"Emerging Paradigms in Engineering Education"

ASEE/PSW-2015 Conference Proceedings

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Edited by
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Foreword

I want to congratulate all those who participated in the 2015 ASEE PSW conference held at National University this past April. This year's theme, "Emerging Paradigms in Engineering Education" appropriately described the changes that have occurred and must continue to occur as educators prepare the next generation of engineers.

There were over 90 submissions which resulted in many excellent papers and posters. As you read these proceedings, you will see a roadmap marked by breadth, depth and innovation that will be used to navigate engineering education. Educators constantly hear that our students are changing. These proceedings demonstrate that our educators are more than prepared for this change.

This conference included educators, researchers and practitioners from industry, academia and government. We were fortunate to have several keynote speakers including: Dr. Don Czechowicz, Project Leader at General Atomics, San Diego, CA; Dr. Muzibul Khan, Corporate Planner, Kyocera Communications, Inc. San Diego, CA; Dr. Justin Opatkiewicz, Lecturer, Nano Engineering Department, University of California, San Diego, CA; and Dr. J. Richard (Rich) Phillips, Professor Emeritus of Engineering, Harvey Mudd College, Claremont, CA.

We appreciate all the conference support from the members of the ASEE-PSW Board of Directors. They provided both suggestions and help throughout the entire process.

A very special thanks goes out to Dr. Mohammad Amin, Dr. Pradip Peter Dey, and Mr. Laith Al Any for their tireless efforts throughout the conference. They conceived the conference idea, solicited abstracts and papers, coordinated the reviewers, and produced the proceedings.

I hope you enjoy the proceedings as much I have and I thank all who made it possible for National University to host this conference.

John Cicero, PhD
Dean of Engineering & Computing
National University
San Diego, CA

Preface

Welcome to the 2015 American Society for Engineering Education-Pacific Southwest (ASEE-PSW) regional conference. The theme of this conference is *"Emerging Paradigms in Engineering Education."* We as university/college educators are responsible for and continuously striving to prepare the next-generation of engineers who will be ready to face the multi-faucet challenges required to move this nation forward. This conference is intended to bring together educators, researchers and practitioners from industry, academia and government to advance engineering and technology education and to encourage wider collaboration between academics and industry. The conference is organized by engineers and for engineers and hosted by National University. The large number of submitted papers is a clear indication of enthusiastic cooperation and response from the community. Out of the 90+ submissions, 57 full papers and 21 posters were accepted based on the reviewers' comments and recommendations. Each submission was reviewed carefully twice (abstract first followed by full paper) by two to four reviewers. These reviewers not only reviewed papers, but also provided their help and support to many authors in order to prepare their final manuscripts. The program committee made their best efforts to accommodate all submissions with academic merit and scholarship.

Many recognized speakers will present their research contributions in their respective fields. In addition, a number of distinguished keynote speakers known both nationally and internationally will deliver their lectures and a group of panelists will attend to discuss the following topic:
" Emerging Paradigms in Engineering and Science Education."

We gratefully acknowledge all the support and help that we have received from the members of the ASEE-PSW Board of Director especially the Chair, Dr. Amir Rezaei for supporting and organizing the conference at National University. We also recognize and show our gratitude to ASEE administration for their cooperation and support. We would like to acknowledge the help and cooperation of all the authors and reviewers of the ASEE-PSW-2015 Conference.

We are grateful to Dr. John Cicero, Dean, School of Engineering and Computing, National University, for his help, guidance and support during the planning, preparation and other phases of the conference. We are also grateful to the keynote speakers: Dr. Don Czechowicz, Project Leader at General Atomics, San Diego, CA; Dr. Muzibul Khan, Corporate Planner, Kyocera Communications, Inc. San Diego, CA; Dr. Justin Opatkiewicz, Lecturer, Nano Engineering Department, University of California, San Diego, CA; and Dr. J. Richard (Rich) Phillips, Professor Emeritus of Engineering, Harvey Mudd College, Claremont, CA.

Our special thanks to Dr. Michael R. Cunningham, Chancellor of the National University System & President of National University, Provost Debra Bean, National University, Dr. Gangaram Singh, Associate Provost, National University, and all faculty and staff of School of Engineering and Computing at National University and sponsors for their help, support, and/or guidance. Thank you.

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San Diego, California
April 10, 2015

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Keynote Speakers

Dr. Don Czechowicz
B.S. University of Southern California
M.S./Ph.D. Penn State University

Dr. Czechowicz is currently Project Leader at General Atomics where he has worked for the last 25 years on a variety of applied technology programs mainly focused on advanced energy development. Previously Dr. Czechowicz was at Los Alamos National Laboratory where he did his Ph.D. thesis research, and was involved in nuclear power programs for space applications. For the past 15 years Don has served as advisor to the UCSD Engineering Honor Society, Tau Beta Pi. In this role Don has been a link between the best engineering students and career opportunities for these students not only at General Atomics but elsewhere in San Diego.

Dr. Muzibul Khan
B.S./M.S. St. Petersburg State University
Ph.D. Concordia University

Dr. Muzibul Khan joined Kyocera Communications, Inc. (KCI), a subsidiary of the global Kyocera Group focused on cellular and mobile devices, in 2013. He is responsible for Corporate and Technology Planning functions, charting the evolution of the business plan and technology portfolio for KCI. Before joining Kyocera, Dr. Khan served in senior leadership roles in the global telecommunications industry, including Chief Technology Officer (CTO) for Huawei Devices USA, Vice President & Head of Research & Development for Nokia CDMA terminals, and Vice President of Product Management & Engineering for the wireless terminals division of Samsung Telecommunications America. He began his career as an associate professor of electrical engineering at Lakehead University, Canada. He has authored more than 30 technical publications and received five patents with several patents pending.

Dr. Justin P. Opatkiewicz
B.S. U.C. Berkeley
Ph.D. Stanford University

Dr. Opatkiewicz joined the NanoEngineering Department at UC San Diego in 2012 to lecture in a variety of core courses in the Chemical Engineering curriculum. He has won the Teacher of the Year Award for both the NanoEngineering department and the Jacobs School of Engineering in 2014. While at Berkeley, Dr. Opatkiewicz created and taught the course Mathematical Techniques for Chemical Engineers. At Stanford, he received multiple teaching awards, including the 2010 Stanford University Centennial Teaching Assistant Award. Following his thesis defense, he was hired to serve as a research mentor in the Bao group at Stanford as well as teach introductory core courses for Chemical Engineering undergraduates.

Honorary Guest Speaker

Dr. J. Richard (Rich) Phillips
Harvey Mudd College
Professor Emeritus of Engineering B.S. University of California, Berkeley, 1956
M. Eng., 1958 and D. Eng. Yale University, 1960

J Richard Phillips was a member of the Harvey Mudd College Engineering faculty for 36 years, serving as Chair for six years and as Director of the Engineering Clinic for 17. During this period, he served as a consultant to a number of Engineering Programs across the United States. In 2012 he was co-recipient of the National Academy of Engineering Bernard M. Gordon Prize for Innovation in Engineering and Technology Education.

He served on the ASEE/PSW Board for over 17 years, first as Vice-Chair for Student Awards, then as Chair in 2002-2003. Until 2014 he continued to serve as Executive Secretary.

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Agile Capstone Integration of Free, Disparate Cloud Services Produced a Prototype Application that Tracks Airborne Wildfire Firefighting Resources

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Abstract

A prototype application designed to leverage state-of-the art cloud computing technologies was developed as a capstone project for U.S. Defense Support to a Civilian Authority mission. The outcome of this paper demonstrates the Agile development and production feasibility of the Modular Airborne Fire Fighting System (MAFFS) Drop Log (MDL) application. Each year, nearly two billion dollars are spent combatting wildfires in the United States. During summer months, fire activity increases to a point where it is in the national interest to call upon the Air National Guard and Air Force Reserve to conduct aerial firefighting operations using USAF C-130 aircraft fitted with the MAFFS technology which creates very capable firefighting air tankers. This application automates a manual Drop Log form that tracks critical firefighting retardant dispersal information and facilitates the federal inter-agency reimbursement process. The MDL application demonstrates how Agile computer development concepts involving a governmental customer, graduate computer science students, and the use of free cloud resources can produce a demonstrable prototype system in less than thirty days. Due to time and budget constraints, this capstone project dictated rapid, inexpensive development and deployment which is ideally suited for Agile development involving cloud technologies. The application's primary functions include maintaining information related to aerial firefighting that can be entered and modified by personnel at diverse locations. Three disparate cloud services, Bitnami, Azure and SugarSync, were integrated to implement MDL. The MDL MySQL relational database was installed on a database server running in Bitnami cloud hosting. In order to perform rapid, Agile development students created an integrated, local, virtual environment running Oracle's VirtualBox and a virtual instance of Windows 7 to create, edit and deploy Bitnami and PHP code. The Bitnami Tracks Stack, based on Ruby on Rails, provided just the right combination of Web Server, Database Server and PHP interpreter the MDL application needed in order to establish this local instantiation of the application. Next, a virtual Windows Server 2012 production instance was created on Microsoft Azure Cloud and the same baseline software tested locally was, also, installed on Azure Cloud. Finally, SugarSync, a cloud file sharing service, was used to tie together a) all cloud platforms b) the local development environment, and c) the Azure production environment in the cloud. Once back on-line, configuration files and web pages automatically synchronized between local, virtualized guest and cloud platforms. SugarSync is employed to provide automatic backup of the data to ensure fault tolerance in both the local development as well as the cloud production environments. Thus, an infrastructure utilizing free cloud services was created to produce a web-deployable application accessible by mobile devices.

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Keywords: Agile development, capstone, cloud services, mobile devices, Ruby on Rails, virtualization

Introduction

Nearly two billion dollars are spent, each year, combatting wildfires in the U.S.[1] (Suppression, 2014). Fire activity increases, each summer, to a point where it is in the national interest to call upon the National Guard and Reserve to conduct aerial firefighting operations using Department of Defense aircraft. This mission set relies on USAF C-130 aircraft crewed by members of the Air National Guard and Air Force Reserve. The Modular Airborne Fire Fighting System (MAFFS) mission is executed in support of the U.S. Forest Service. MAFFS, converts USAF C-130 aircraft into very capable firefighting air tankers. These MAFFS aircraft dispense up to 3,000 gallons of fire retardant in 5 seconds on vegetation source fuels ahead of a wildfire[2] (California Department of Forestry and Fire Protection, n.d.) as shown in Fig. 1.

Figure 1. MAFFS drop of retardant. (U.S. Air Force photo)

The “MAFFS Drop Log” is a manual form used to capture aerial firefighting operations data for accounting purposes. The Drop Log is the sole source of information used by U.S. federal and state government agencies to determine funding budgets to fight escalating numbers of annual wildfires. The MAFFS mission is in support of the U.S. Forest Service that is part of the Department of Agriculture. Under provisions of law[3] (U.S. Economy Act, 2014, 31 U.S.C. §1535), the Department of Agriculture must reimburse the Department of Defense for its support of this vital mission.

This paper demonstrates the Agile development and production feasibility implementation of a MAFFS Drop Log database management system (DBMS) developed using free cloud services. This system is used to replace the manual process of logging, and is referred to as the MDL-System. The MDL-System is a master’s degree Capstone project developed by author Allen in the Computer Science (MSCS) program of the School of Engineering and Computing (SOEC) of National University (NU). In this project, the MAFFS Drop Log is converted to digital format, providing rapid access to firefighting activity and processes, and proves the feasibility of using

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advancing mobile technologies to improve timely and accurate management of the MAFFS process.

The MDL-System is a collaborative research initiative that uses leading-edge, innovative teaching and technological techniques: Agile project development, a collaboratory, and state-of-the-art cloud technologies. This project, completed in two months, is an example of not only research but beneficial implementation of innovative pedagogy and experiential learning to create a useful product.

A. *Agile Pedagogy, Project Development and Process Management*

MDL-System was developed using the Agile development process. According to the *Manifesto for Agile Software Development*[4] (2014), Agile defines a culture that values individuals and interactions over processes and tools and delivers productive solutions in record time.

Customer satisfaction through early and continuous delivery of valuable software is the highest priority of Agile development. The process welcomes change and harnesses change for competitive advantage. It focuses on delivering working, modular software frequently, through daily interaction between the customer and developer throughout the project. Agile entrusts project development to talented, motivated individuals, supported by the tools and environment they need to excel. People, communications, product delivery, and flexibility are important Agile concepts.

Although originally created for software development, Agile principles have been applied to any process—software development, project management, and teaching. Management of the national MAFFS program is an example of Agile concepts in process management. The development of MDL-System is an example of both Agile pedagogy and Agile application development.

B. *Collaboratory*

A collaboratory is defined as being “virtual” and promoting “working together apart”[5] (Kouzes, Myers, & Wulf, 1996), which has been perceived to significantly increase the output and productivity of researchers. Collaboration is at the heart of science. NU finds satisfaction in being involved in community service and supporting advanced education of U.S. military personnel. This paper reports a collaborative research effort between (a) NU and its community service support of wildfire management, (b) the SOEC Master of Science in Computer Science program, (c) a graduate student with vision (author Allen), who is a recognized national subject-matter-expert on MAFFS, and (d) Colonel Brian Kelly, Vice Wing Commander of the 146th Airlift Wing, Channel Islands Air National Guard in California, the sponsor of this project. Beneficiaries of this research are residents not only in Southern California but throughout all of California and other western states at large.

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C. *State-of-the-Art Cloud Technologies*

The use of virtualization technology is particularly useful in the teaching of computer science and information technology curricula. This is an example of Agile teaching, dynamically adjusted to meet the needs of the students and course material. In a rapidly evolving technological space such as that developing with cloud infrastructures, both instructors and students must utilize Agile concepts, particularly in the NU course-per-month modality.

In this paper, Allen illustrates the power of using multiple public cloud CSPs—Azure, Bitnami, and Maestro—at minimal or no cost.

A Glossary of Information Technology and Other Terminology used in this paper is provided at the end of the paper.

Background

A. *Wildfire Suppression History*

Annual suppression cost of wildfires has exceeded $1 billion in each year since 2000, according to the senior climate economist with the Union of Concerned Scientists. The average number of big western fires has risen from 140 per year in the 1980s to 250 in the 2000s[6] (Rice, 2014). NASA EO-1 satellite images of southern California just south of Escondido, shown in Figures 2 and 3, reveal the active fire zones and smoke plumes in October 2007, and an infrared image showing the actual blazes[7] [8] ("Witch Fire," 2013; "October 2007 California Wildfires," n.d.).The October wildfires in California totaled about 30, with 17 of them being major fires. Over 1,500 homes were destroyed, and approximately 970,977 acres (1,500 square miles) were burned from Santa Barbara to the Mexican border. Fourteen people died in these fires. Some 1,000,000 people had to evacuate their homes in the largest evacuation in California's history. The Witch fire displaced more people than were evacuated by Hurricane Katrina in 2005. According to many civil firefighting agencies, the Modular Airborne Fire Fighting System is desperately needed for combating wildfire disasters.

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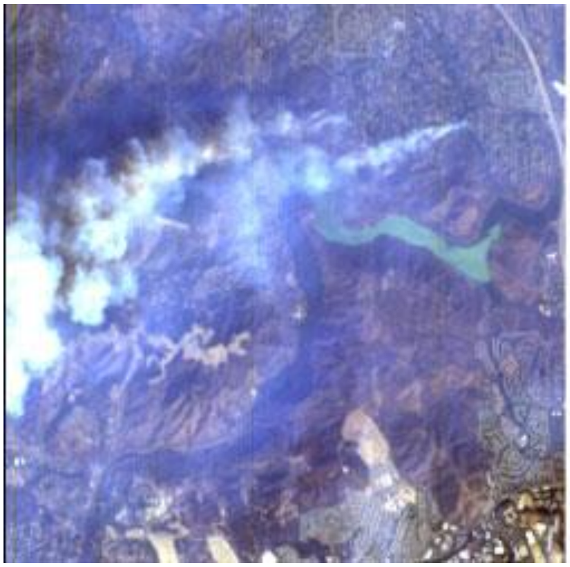

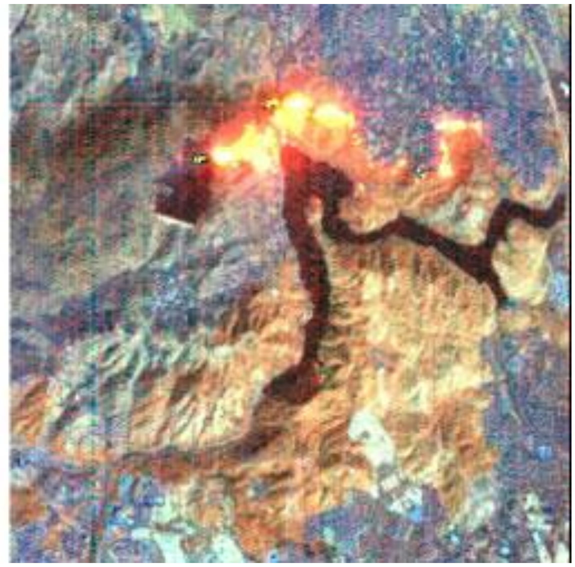

Figure 2. NASA photo, October 23, 2007 *Figure 3.* NASA Infrared photo

B. ***Modular Airborne Fire Fighting System (MAFFS)***

During daily operations of a MAFFS aircraft, information regarding each mission is manually logged on a form called a Drop Log. The Drop Log is used as a source document, providing the location and quantity of fire retardant that was dispensed during each flight sortie. This information is used to validate U.S. Forest Service expenses related to fighting fire and for statistical purposes to provide feedback on the effectiveness and efficiency of the aerial firefighting program. One of the authors (Allen), by Air Force assignment, was one of the primary contributors in the specification of the Drop Log, in use for the past decade, and thoroughly understands the function of each data element and the Drop Log process.

Purpose of the MAFFS Drop Log Application

The MAFFS Drop Log Application System (MDL-System), the subject of this paper, was developed as a master's graduate project in the MSCS program. It was created in response to a need perceived by Allen, an Air National Guard pilot, assigned to the MAFFS wildfire firefighting program. Although Department of Defense (DoD) and Department of Agriculture (DoA) constraints on automated systems make operationally deploying such an application administratively difficult, the MDL-System demonstrates the usefulness of such an application and validates the need for more formal, DoD/DoA-driven, application development.

The objective of this research project is to implement a digital capture of MAFFS Drop Log data using or providing the following:

1. Agile system development concepts directed by standards
2. Cloud infrastructure resources (IaaS)

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3. Cloud development resources (SaaS)
4. Cloud operational resources (PaaS)
5. A relational database management system (RDBMS)
6. A normalized relational database
7. A portable system
8. Client-server architecture that supports multiple users
9. Standard browser interface (iPad capable)
10. Dynamic update of MAFFS Drop Log information
11. Cost-free development computer resources
12. Demonstration of innovative pedagogical and developmental research tools

A. ***Functions***

During the daily operations of a MAFFS aircraft, information regarding the mission is logged on a form called a Drop Log. The Drop Log is used as a source document that provides the location and quantity of fire retardant that was dispensed. This information assists U.S. Forest Service validation of expenses related to fighting wildfires in the U.S.

The Drop Log is maintained by the Co-Pilot or Navigator on board the C-130. It is updated throughout the day with information that includes the specifics of the aircraft used, the name of the aircraft commander, where and how much retardant was loaded, where it was dispensed, and in how many increments it was dropped. This information is also used for statistical purposes, providing feedback on the effectiveness and efficiency of the aerial firefighting program.

B. ***Application Delivery***

The fully functional proof-of-concept application is accessible through hypertext Internet protocol via industry-standard web-browser clients. An unlimited number of clients run custom server-side interpreted PHP code, provided by an Apache[9] web server integrated with a MySQL database server backend[10] (Apache, 2014; Oracle Corporation, n.d.). The entire server-side system, encapsulated in the Bitnami Tracks Stack[11], resides in the cloud, hosted on a virtual instance of Microsoft Server running on the Azure cloud service provided by Microsoft[12] (Bitnami, 2014; Microsoft, 2014).

Useful Tools for Agile Development

Student success in the NU one-course-per-month modality is enhanced by Agile use of technology[13] [14] [15] [16] (Dey et al., 2009; Katz, 2011; Romney, 2009; Sahli & Romney, 2010). Specific tools that have proved extremely productive are virtualization, Ruby on Rails framework, and cloud infrastructure.

A. ***Virtualization***

The National Institute of Standards and Technology defines virtualization as the simulation of software and/or hardware solutions[17] (Scarfone, Souppaya, & Hoffman, 2011). The individual environment is called a virtual machine (VM), and VMs facilitate operational efficiency, testing

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environments, better organizational control and security, and portable encapsulation. Another benefit of virtual environments, however, is to provide students with a tool that makes Agile development possible, as one does not have to physically have a multitude of different computers. Virtualization is part of the fundamental technology that has made cloud infrastructures possible and facilitated the rapid adoption of cloud concepts.

B. *Ruby on Rails Framework*

Ruby on Rails is a web framework that uses Model-View-Control (MVC) design to organize application development. In the MDL-System, the author drew upon an application written in Ruby on Rails to leverage an environment encapsulating a valuable combination of database and web server systems. The history of its successful usage of Ruby on Rails in teaching is reviewed in a journal article[18] (G. W. Romney, M. D. Romney, Sinha, Dey, & Amin, 2014). RoR software development is based on Agile principles[4 19] (Manifesto, 2014; ”What Is Rails?” 2014).

C. *Cloud Infrastructure*

Virtualization and deployment of cloud infrastructures go hand in hand with the use of Agile pedagogy[20 21 22] (Anderson & Romney, 2013; Anderson & Romney, 2014; Romney, Amin, Dey, & SInha, 2014). Allen, as a graduate student, made use of virtualization and public cloud infrastructures in DAT605. This experience proved so Agile and successful that Allen elected to extend the same development tools to the MDL-System MSCS Capstone project in CSC686-7.

The MAFFS Retardant Drop Log Application

The MDL-System uses client-server architecture. A client computer (laptop, desktop or iPad) was used to interact with servers located in the cloud. In this specific implementation, Microsoft Azure Cloud was used as the cloud service provider to enable a web server and a database server.

A. *Client, Server and MySQL Database Server Operating Environment*

Client. MAFFS Drop Log Client is designed to run on all popular variants of web browsers, including Microsoft Internet Explorer, Google Chrome, Apple Safari, and Mozilla Firefox. The client computer used was a Windows 7 environment and an iPad using Apple Safari.

Servers. MAFFS Drop Log Server runs the MySQL Database Management Server, Apache Web Server, PHP code interpreter, and server-side application scripts on a Microsoft Windows Server 2012 foundation, hosted virtually on the Microsoft Azure cloud service provider. MAFFS Drop Log Database Server is a MySQL database used in the creation and maintenance of the MAFFS Drop Log database.

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B. ***Hardware and Software Interfaces***

MDL-System resided on a virtualized server, hosted by Azure Cloud. No additional hardware is required other than the client laptop. The application may be installed in a private infrastructure, or cloud, if required by operational security.

Bitnami is a software-as-a-Service (SaaS) cloud service provider that provisions complete web frameworks for development purposes. Tracks is a specific application and is an example of a Bitnami stack that uses Rails, Apache, MySQL, and PHP as its development framework. Bitnami Tracks was used for the development of the MDL-System which was ultimately deployed in a production mode on Azure Cloud.

Maestro, a SaaS cloud service provider that provisions SQL-related software development tools, was used, also, in the development phase.

Finally, SugarSync, a cloud file sharing service, was used to tie together a) all cloud platforms listed above, b) the local development environment, and c) the Azure production environment in the cloud. Once back on-line, configuration files and web pages automatically synchronized between local, virtualized guest and cloud platforms. SugarSync is employed to provide automatic backup of the data to ensure fault tolerance in both the local development as well as the cloud production environments.

C. ***The MAFFS Drop Log Database***

MDL-System translates a manual form, called the MAFFS Drop Log, to a MySQL Relational Database Management System (RDBMS) database. The MAFFS Drop Log is used to document the activities of a single fixed-wing aircraft throughout one day of wildfire firefighting operations. A sortie is the result of a request by the incident. Many aircraft can fly to the incident, each having an Aircraft Commander flying it.

D. ***Drop Log Database Entity Relationship Diagram***

A relational database is made up of entities, attributes, and relationships. This is graphically represented by a diagram that helps a developer to correctly design the associated database. Once the entity relationship diagram (ERD) is defined, the database is implemented using a relational database management system (RDBMS) such as MySQL, Oracle, MS SQL, or PostgreSQL. A RDBMS stores data in tables, in which every row represents an entity or record. Each record, in turn, consists of attributes or columns. The Drop Log ERD is shown in Fig. 4.

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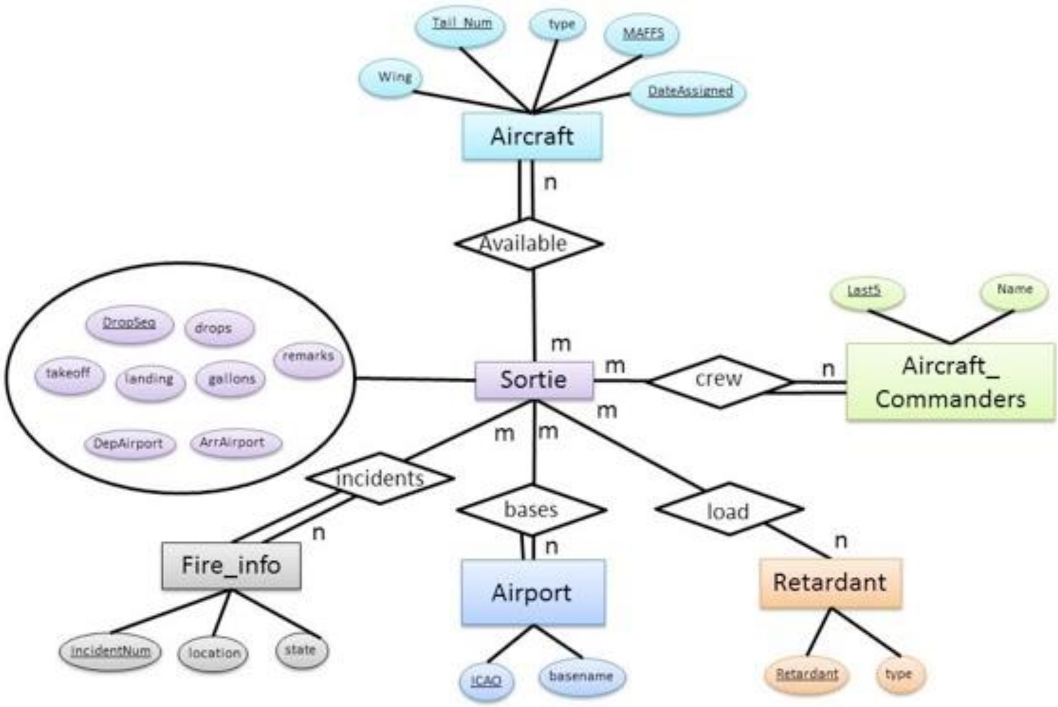

Figure 4. Drop log database entity relationship diagram.

E. ***Drop Log Normalization***

To minimize database anomalies, Codd advocated imposing relational database normalization rules to a level of third normal form (3NF). "When tables are not in the third normal form, either redundant data exists in the model, or problems exist when you attempt to update the tables"[23] (Codd, 2014, n.p.). Following these rules, the Drop Log database was normalized to 3NF as is shown in Allen and Romney[24] (2015, March).

F. ***Representative Drop Log Database Tables***

Once the Bitnami Tracks Stack is installed, the MAFFS Drop Log Database can be created. Using the phpMyAdmin application (or through a console connection to MySQL), MySQL scripts were executed to create the database and tables. Sample data, which was then inserted using insertion scripts and query scripts, verified that the server produced the expected results shown in Fig. 5.

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MAFFS Drop Log Tables

Aircraft

MAFFS	DateAssigned	Tail_num	Wing	type
char(2)	datetime	char(5)	char(5)	char(7)
4	1400 4Apr2014	21461	146AW	C-130J
6	1400 4Apr2014	21466	146AW	C-130J
8	1600 6Apr2014	81451	145AW	C-130H
9	1600 6Apr2014	81453	145AW	C-130H

Aircraft Commanders

Last5	Name
char(5)	varchar2(32)
12345	Allen
99876	Davis
66543	Smith
22334	Jones

Airports

ICAO	basename
char(4)	varchar2(32)
KSBD	San Barnardino
KCDC	Cedar City
KNTD	Point Mugu
KWJF	Lancaster/Fox

Fire_Info

IncidentNum	Location	state
varchar2(6)	varchar2(32)	char(2)
P1340	Whiskey Flats	UT
P2190	Rim	CA
C9190	Waldo Canyon	CO
U3352	Laughing Donke	UT

Retardant

Retardant	type
varchar2(6)	varchar2(32)
D75	Phoschek D75
P100	Phoschek P100
LC95	Phoschek Liquid Concentrate 95

Sortie

DropSeq	IncidentNum	Last5	MAFFS	DepAirport	ArrAirport	Retardant	takeoff	landing	gallons	drops	remarks
number	varchar2(6)	char(5)	char(2)	char(4)	char(4)	varchar2(6)	datetime	datetime	float	number	varchar2(256)
Relation:	*IncidentNum*	*Last5*	*MAFFS*	*ICAO*	*ICAO*	*Retardant*					
1	P1340	12345	4	KSBD	KSBD	D75	1125 28Jul14	1345 28Jul14	2888.3	2	L-45
2	P2190	99876	8	KWJF	KWJF	D75	1450 28Jul14	1530 28Jul14	2986.3	3	L-35
3	U3352	66543	6	KCDC	KCDC	LC95	0942 28Jul14	1136 28Jul14	2986.3	3	L-35
4	U3352	66543	6	KCDC	KCDC	LC95	1202 28Jul14	1334 28Jul14	2999.4	1	L-35
5	U3352	66543	6	KCDC	KCDC	LC95	1512 28Jul14	1636 28Jul14	3012.8	1	L-35

Figure 5. Representative Drop Log database tables.

MDL-System Implementation

A. *Secure an Account on Microsoft Azure*

The MAFFS Drop Log relies on the third-party, platform-as-a-service (PaaS) provider Microsoft Azure Cloud. User account creation was straightforward and as outlined on the Microsoft Azure website (http://azure.microsoft.com/). A free-trial account was created for the development of the project application.

B. *Create a Microsoft Server 2012 Virtual Machine on Azure*

After an Azure account was created, the administrator logged in and created a new Virtual Machine. From the available images, Windows Server Essentials Experience was selected. This version seemed well provisioned for the project. Creating the server instance was fairly straightforward. Once the MS Server 2012 was instantiated and executing, a connection was made using the Microsoft Remote Desktop Connection (RDC) application to access the MS Server 2012 virtual machine.

C. *Install the Bitnami Track Stack into the MS Server 2012 Instance*

From within the RDC, the Mozilla Firefox web browser and Notepad++ text editor applications were installed to speed and facilitate development. Using Mozilla Firefox, and the cloud SaaS, Bitnami Tracks Stack was downloaded from https://bitnami.com/ and installed. Once installed, the Bitnami Tracks application was started. The MySQL database server, Apache web server and

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PHP interpreter were started as background processes. Once the installation was complete, the Tracks application was initiated to verify that each sub-server was executing.

D. ***Create the Drop Log Database Using SQL Scripts***

Structured Query Language (SQL), is a computer scripting language used to operate on relational databases with a set of operators based on Codd's relational calculus to define and manipulate data elements, including the script operators needed to populate the tables with data. SQL was used with the MySQL database server initiated in the previous step for these operations.

E. ***Install and Run the PHP Generator for MySQL from SQL Maestro***

After the database was created in Azure Cloud, the application was downloaded to a Windows 7 laptop and executed to generate a web-based front end for data entry and report generation. The PHP application from the cloud SaaS, SQL Maestro (www.sqlmaestro.com) called "PHP Generator for MySQL," was downloaded at no charge.

F. ***Security Requirements***

Access controls. Data maintained in the MAFFS Drop Log database is unclassified, and is protected by username and password for authentication. Use of Secure Sockets Layer (SSL) encrypted pipelines would enhance security but are not mandated.

User account management. Because simplicity is paramount in the initial release, usernames and passwords will be managed centrally by a Military Administrative Specialist or Forest Service staff member. This may be accomplished through the PHP-generator application. Usernames and passwords are maintained on the server.

MDL-System Demonstration

The MAFFS Drop Log application is accessed through a standard web browser using the address of the server. A variety of browsers, running on several different platforms, were tested. These include Microsoft Internet Explorer, Apple Safari, and Google Chrome, running on Windows versions 7 and 8, Apple OSX 10, and on an Apple iPad and iPhone running iOS version 7.

The application is structured such that a table of data is selected through a link on the upper left of the screen. Once selected, data in that table may be added, changed, or deleted. As an example, selecting *Aircraft* brings up the list of aircraft currently stored in the database. A new aircraft can be added, or existing aircraft may be edited or deleted. This process is duplicated with each of the other tables.

A. ***Laptop Browser***

The tables accessible from the links on the left side of the page include *Aircraft*, *Aircraft Commanders*, *Airports*, *Fire Info*, *Retardant*, and *Sortie*. Two queries are available, *Drop Log Format* and *Utah Fire Info*. These queries demonstrate how data may be retrieved from multiple

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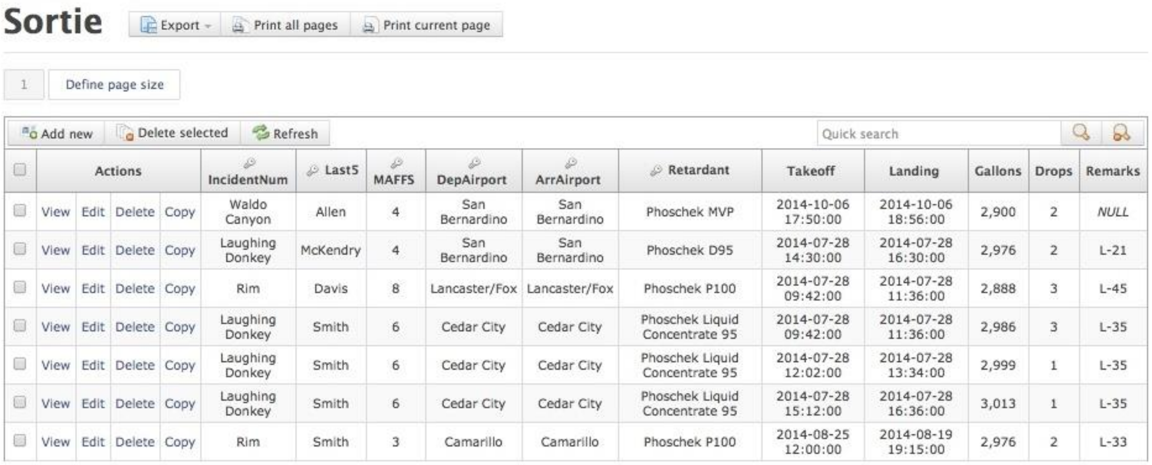
tables to produce a single, more readable output. The Drop Log Format mirrors the manual Drop Log form from which the project is rooted. The screen is shown in Fig. 6.


Sortie   Export   Print all pages   Print current page

1   Define page size

Add new   Delete selected   Refresh   Quick search

	Actions				IncidentNum	Last5	MAFFS	DepAirport	ArrAirport	Retardant	Takeoff	Landing	Gallons	Drops	Remarks
	View	Edit	Delete	Copy	Waldo Canyon	Allen	4	San Bernardino	San Bernardino	Phoschek MVP	2014-10-06 17:50:00	2014-10-06 18:56:00	2,900	2	NULL
	View	Edit	Delete	Copy	Laughing Donkey	McKendry	4	San Bernardino	San Bernardino	Phoschek D95	2014-07-28 14:30:00	2014-07-28 16:30:00	2,976	2	L-21
	View	Edit	Delete	Copy	Rim	Davis	8	Lancaster/Fox	Lancaster/Fox	Phoschek P100	2014-07-28 09:42:00	2014-07-28 11:36:00	2,888	3	L-45
	View	Edit	Delete	Copy	Laughing Donkey	Smith	6	Cedar City	Cedar City	Phoschek Liquid Concentrate 95	2014-07-28 09:42:00	2014-07-28 11:36:00	2,986	3	L-35
	View	Edit	Delete	Copy	Laughing Donkey	Smith	6	Cedar City	Cedar City	Phoschek Liquid Concentrate 95	2014-07-28 12:02:00	2014-07-28 13:34:00	2,999	1	L-35
	View	Edit	Delete	Copy	Laughing Donkey	Smith	6	Cedar City	Cedar City	Phoschek Liquid Concentrate 95	2014-07-28 15:12:00	2014-07-28 16:36:00	3,013	1	L-35
	View	Edit	Delete	Copy	Rim	Smith	3	Camarillo	Camarillo	Phoschek P100	2014-08-25 12:00:00	2014-08-19 19:15:00	2,976	2	L-33

Figure 6. All Sortie information.

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B. *iPad Browser*

The same Sortie information, as previously shown, but on an iPad iOSv7 browser as shown in Fig. 7.

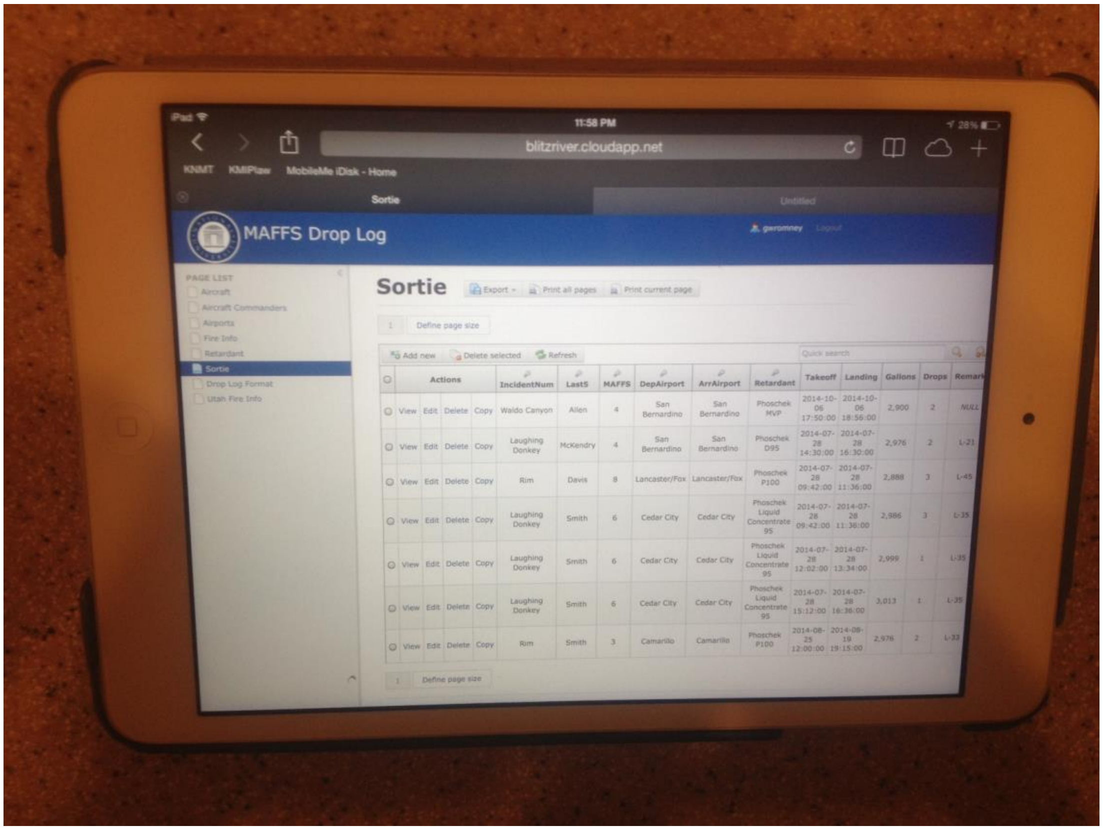

Figure 7. All Sortie information displayed on an Apple iPad

Conclusion

The MDL-System was a collaborative research initiative that used leading-edge, innovative teaching and technological techniques: a collaboratory, Agile project development, and state-of-the-art cloud technologies. This project, completed in two months, is an example of not only research but beneficial implementation of innovative pedagogy and experiential learning to create a useful product. Student success in the NU one-course-per-month modality was enhanced by Agile use of technology. Specific tools that proved extremely productive were virtualization, Ruby on Rails framework, and cloud infrastructures.

The objective of this research project was to implement a digital capture of MAFFS Drop Log data satisfying the twelve objectives previously listed. All twelve objectives were accomplished.

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Regarding the specific research objectives of using leading-edge and innovative teaching and technological techniques, these also were most successful and are recommended for further utilization. The ability to use cloud and mobile devices by using standard browser display expands the potential usefulness of all these technologies together.

A. ***Collaboratory ("working together apart")***

The client, Colonel B. Kelly, was continuously involved by the Project Lead, Allen, in the development process, which ensured a successful project delivery. An industry collaborator, Spork Labs Ltd., provided fundamental guidance in utilizing Bitnami stacks for Ruby on Rails framework training at a critical stage. The MS Computer Science Lead Faculty, Dr. Dey, provided guidance and counsel in a timely manner. Additionally, the manner in which the students in DAT605 worked as a team under the direction of the project lead was most collaborative.

B. ***Agile Project Development***

The project lead utilized Agile concepts in working with both the client, Colonel B. Kelly, and his instructor, Dr. Romney. Challenges were addressed, and modifications were made dynamically.

C. ***State-of-the-Art Cloud Technologies***

Cloud technologies were discovered by the project lead, analyzed, and then selected in accordance with the Agile process. The synergy between collaboration, agility, and cloud produced a remarkable exercise in innovative research in both pedagogy and technology to produce a very functional product in the MDL-System.

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Glossary of Information Technology and Other Terminology

AEG-WFF. Aerospace Expeditionary Group, Wildland Fire Fighting, is the military organization created to support the aerial firefighting program.

Agile. Ability to move quickly as applied to pedagogy, delivery, development, and management.

Authentication. Validating identity of a person or object.

Azure. Microsoft cloud service provider that provides both PaaS and IaaS services that support many programming languages, tools, and frameworks.

C2 Center. AEG Command and Control Center. It is the responsibility of C2 Center staff to collect, record, and audit information related to all aspects of aerial firefighting activity.

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Cloud. The Internet or network of computing resources. May be either public or private.
Cloud computing. The delivery of computing resources or services over the Internet.
Collaboratory. Coined by the National Science Foundation to identify a laboratory consisting of collaborating colleagues.
Cyber security. The discipline of securing computer resources and information.
Hypervisor. Computer software or hardware that manages and executes virtual machines.
IaaS. Infrastructure as a Service cloud resource. Azure is an example of an IaaS. The provisioning of virtual machines with Microsoft operating systems, as its first priority, is one of its services.
Infrastructure. Physical computing hardware and resources that are part of a network, a cloud, or the Internet.
Maestro. A SaaS cloud service provider that provisions SQL-related software development tools. www.sqlmaestro.com.
MAFFS. Modular Airborne Fire Fighting System program of the U.S. Department of Defense in support of the U.S. Forest Service that is part of the Department of Agriculture.
MDL-System. MAFFS Drop Log Application System prototype developed as a National University Master of Science in the Computer Science program of the School of Engineering and Computing.
MDLAPS. MAFFS Drop Log Application Project Specification of the MDL-System.
Mobile cloud computing. Comprises three heterogeneous domains: mobile computing, cloud computing, and wireless networks.
Mobile device. A portable computing device that is most often hand held, such as an iPad, notebook, or smartphone that uses a wireless network.
Module. A procedure or process.
MySQL. An open-source relational database management system that uses tables of rows and columns of data, and defines the relationship of the data elements.
Normalization. E. F. Codd established a number of rules for a RDBMS that eliminate data anomalies such as data redundancy that are referred to as RDBMS Normalization to at least a Third Normal Form (3NF) level.
PaaS. Platform-as-a-service cloud resource. Azure is an example of a PaaS. The provisioning of MySQL database servers is one of its services. Ruby on Rails as a programming framework is one of its services. Bitnami that uses Rails is one of its services.
PHP. A server-side computer scripting language used for web development.
Private cloud. A cloud that is private to an enterprise and may be physically local to the user.
Public cloud. A cloud available to the public at large and normally physically remote from the user.
RDBMS. Relational database management system that follows the rules of Codd's Relational Calculus and uses tables with rows (entities) and columns (attributes) that are linked by relations.
SaaS. Software-as-a-service cloud service provider. Bitnami is an example of a SaaS.
SQL. Structured Query Language, a computer scripting language used to operate on relational databases with a set of operators based on Codd's relational calculus to define and manipulate data elements, and to generate reports of the resulting operations.
SSL. Secure Sockets Layer encrypted tunnel.

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Stack. A software configuration that contains all of the software modules to provide a development environment. Such modules include an operating system, web server, database server, and development resources. Bitnami is a cloud service provider that facilitates stacks of various configurations. Tracks is an example of a Bitnami stack that uses Rails, Apache, MySQL, and PHP as its development framework.

SugarSync. File archival and synchronization services through sugarsync.com.

Virtual machine. An instance or emulation of a real, physical computer with its own segmented, private, unshared operating system and memory space.

Virtualization. The act of using a hypervisor and virtual machines to provide a virtual, non-physical computing resource environment.

VM. A virtual machine.

Wi-Fi. Wireless technology that uses high-frequency radio waves to send and receive data and normally connects with the Internet.

Wildfire. A wilderness-area fire that is wind driven, fueled by vegetation, and distinguished by its extensive size and speed of propagation.

Wireless network. A computing infrastructure that supports cable-less connectivity of computing and mobile devices, frequently through Wi-Fi technology.

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Emerging Paradigms in Engineering and Science Education

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Abstract

Old educational paradigms such as behaviorism and constructivism served industrial growth and expansion by supplying work force with conformity and standards. With the recent advances in automation and social changes, questions are raised about the current adequacy of these paradigms. In the coming decades, growth of diversity of talents would be more appropriate than conformity of skills measured primarily by multiple choice tests, because creative problem solvers increasingly are in demand. Some of the legendary engineers, such as Steve Jobs and Bill Gates were college dropouts. There are several emerging alternatives that involve distance learning that need to be considered in order to investigate the real issues in engineering and science education. Some of the pertinent questions about any engineering program are: (1) How well do the program learning outcomes, teaching practices, and course materials prepare graduates with the required skills and knowledge for innovative problem solving? (2) What are the changing roles of media, learning environments, behavioral factors, perceptions and social factors? (3) Are there emerging alternatives that appear to be better than current practices?

Past pedagogical practices appear to not address these questions adequately. This paper critically examines past pedagogical practices and assesses approaching trends accelerated by Cloud technologies, social networking and the mobile devices that characterize some of the emerging paradigms in engineering and science education. Highlighting evidence from various sources a discussion is initiated in order to examine controversies about trends in emerging paradigms and their implications.

Key words: Agile, cloud, distance learning, educational paradigms, experiential learning, innovative problem solving.

Introduction

Crouch[1] states in a Reader's Digest article that "research universities are no place for undergraduates. Professors at big research universities are often more interested in doing research with graduate students than teaching your child. . . . So, they tend to host huge lectures and then foist undergrads off on teaching assistants who may or may not be supervised" (page

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180). Like Crouch, the authors of this panel discussion paper are also concerned about general educational environments and more specifically about engineering and science education. The authors openly discussed the pros and cons between the major traditional educational paradigms and the new emerging paradigms without reaching any consensus. It is realized that it would be appropriate to raise some of the important issues and differences here in order to more openly discuss them with the audience during the panel discussion session. Differences of opinion between the authors may lead to passionate debates during the panel discussion session with new perspectives.

The U.S. is losing its leadership in science, technology, engineering, and math (STEM) education, according to a 2007 report[2], "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future". Additionally, other concerns about the quality and effectiveness of teaching learning environments in the U.S. are also registered. Educational paradigms that served us well in the past may not be adequate for the future. We live in a rapidly changing world, with a global job market, global educational competition, a globally integrated economy[3], conflicting educational values, increasing multicultural trends, burdening educational cost, rising security crisis, growing ethical and moral conflicts, widening income gaps, and unstable financial conditions. Some strategic actions are needed for preventing further deterioration of educational health. After reviewing current research sources, Wallis[4] concludes that "Recent test results show that US 10th-graders ranked just 17th in science among peers from 30 nations, while in math they placed in the bottom five" (p. 28)[i]. As a result many students come to colleges without appropriate preparation for higher education in STEM. Undoubtedly, continuation of this trend is a danger to U.S. economic growth, security, standard of living, future technological development, and world leadership.

It may be argued that a new class of creative engineers and scientists will be needed for solving the problems of the coming decades. These engineers would be able to compete in the global job market if they acquire innovative problem solving skills via creatively advanced educational environments. That is, what counts for the coming years is the type and robustness of education. Well-developed problem solving skills has provided critical advantage to individuals, families, groups, communities, and nations. Great nations are built by great problem solvers, and education is the most important system for developing and enhancing problem solving skills. Well-educated engineers, technologists and scientists are in demand due to global competition. In order to build a vigorous economy with sustainable growth, creative educated modern problem solvers are needed in the U.S[5]. As the nature of the problems changes, new approaches are needed for solving them and these new approaches are perfected in educational institutions. Regrettably, our colleges and universities are not able to produce modern inventive problem solvers. Several recent strategies show increased improvement in student learning in some specific cases[6]. However, nationwide enhancements have not been realized despite these isolated successful cases. A new innovative approach with a distinctive combination of development of diversity of talents, agile teaching, new technology and innovative problem solving may bring rapid changes to our pedagogical processes.

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The concept of paradigm is used in this research from Thomas Kuhn[7] in a broad sense without any attempt to redefine it. The concept of emerging paradigm implies that a new framework is required for making new significant developments which are inconsistent with the old paradigm. Making improvements in the old paradigm would make some enhancement in the old paradigm. However, if the old paradigm is broken it may be better to replace it with a new paradigm. For the purpose of this paper, it is important to characterize the emerging paradigm adequately so that new proposals can be considered for future developments.

Old Paradigms

The old paradigms have served humanity well in the past. They have produced a huge homogenous work force needed by industry. Planned work force development has helped in the past for the job market at a specific point in time. The work force in the past two centuries was generally geared towards industry needs based on conformity rather than creativity. Among the well-known educational paradigms were behaviorism, constructivism, and cognitivist theory.

B. F. Skinner, one of the main proponents of behaviorism, developed his idea of stimulus response and the role of reinforcement[8, 9] in the learning theory. He argued that a human action is the result of the consequences of the same action. If the consequences are positive the action that led to it is likely to be repeated; if the consequences are negative, the action is not likely to be repeated. According to behaviorism, a learner learns by responding to environmental stimuli.

Noam Chomsky and his followers critically examined behaviorism and developed cognitivist theory of learning as a viable alternative to behaviorism[10]. According to this paradigm, learning is a complex cognitive process where the learner is an information processor who can learn without external stimuli. One may become interested in learning something new based on questions generated by the learner from his reasoning with existing knowledge. Cognitivist theory has been one of the most dominant learning paradigms of the past few decades.

According to constructivism, every learner constructs her ideas and views based on her experience, interactions and other learning activities. That is, a learner generates her knowledge and meaning. Constructivist theories have been very influential throughout much of the non-formal learning sector[11].

Barrows[12] is given credit for the classic model of Problem Based Learning (PBL), which has two key features: “a rich problem is used that affords free inquiry by students, and learning is student-centered”[13]. PBL is the educational process by which problem solving activities and the guidance from an instructor facilitate learning. PBL is the pathway by which students “learn how to learn”. It challenges students to think critically, analyze problems, be pro-active, and discover and use pertinent learning resources[14, 15, 16].

Emerging Paradigms

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Is the growth of digital media transforming how we communicate with each other? Are new technologies changing our essential habits, and the ways in which we think, learn, teach, author, and publish? With the help of new media a new approach to education may allow us to develop diversified, creative, innovative problem solving workers. Are there other forces that motivate new educational paradigms?

Ordonez and Ramler[17] argue that "Critical problems of inequity and polarization have now far outpaced the efforts of education systems to reform themselves. These realities call for systemic changes in the approaches to education and a readiness to accept new paradigms to guide educational policies and practice." (page 28). Through the power of innovative engineering technologies, age-old obstacles to human interaction and globalization, like geography, language and limited information, are falling and a new wave of connectivity, communication, creativity and potential is rising[18]. There is an opportunity to develop the potential of the individual learner, so that she can concentrate on her interest and develop it to the fullest extent. The use of computers in engineering education introduced a highly self-directed form of learning in engineering. Computers can be used for simulation of highly complex concepts and systems in engineering and they are becoming a vital component of tools used in new paradigms in engineering.

The flipped-classroom approach with the Khan Academy delivery method [ii] shows enormous potential for a viable alternative to old paradigms in education. It has drawn considerable attention among learners, teachers, investors, and philosophers[19]. This new approach in teaching is a pedagogical model in which a lecture, consisting of a "talk" in front of the classroom by the instructor, is replaced by short video lectures viewed by students remotely before the class session. This focuses in-class time to group problem solving, presentation of projects and interactive discussion of topics by students. The video lectures are the key ingredient in the new flipped approach. With emerging computer technology such lectures can be created and the most complex concepts in engineering can be succinctly explained by animation and simulation, and viewed repeatedly as needed by students both before and after they attend the lecture. Or, in an online modality, they replace the lecture. With emerging, powerful mobile technology the class educational resources and videos can easily be accessible by students at times and places, with miniature mobile devices, that were not previously possible. "According to Inside Higher Ed, a recent study by the Campus Computing Project showed that more than two-thirds of U.S. colleges and universities are already, or willing to start, using lecture-capturing software to make lectures available to students at home—the gateway to a large-scale flipocracy. Proponents argue that flipping courses inspires students, gives them more control over their own learning, and frees more class time for meaningful interaction . . ."[20]

The flipped classroom changes the role of instructor from delivering lectures to engaging students in problem solving and experiential, hands-on exercises during the class-time. The emerging new paradigm of flipped classroom places the responsibility for learning on the students and gives them encouragement, and opportunity while building self-confidence, for experiments and problem solving. However, the flipped classroom model introduces students to

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an environment of reduced face-to-face lectures. This will have particular impact upon students who learn best from personal lectures presented in person by professors. These are among the topics that the authors of this paper would like to open to public contribution in a panel discussion scheduled at this regional conference.

Robinson's philosophy of development of diversity of talents for creative problem solving in new learning environments calls for a paradigm shift in education[21, 22]. He argues that one needs to find his or her element, and nurture and develop it through education[22]. Often very creative persons, such as Steve Jobs, drop out of traditional college because they cannot nurture their primary interest. Those who stay in college in those circumstances endure it and do their best to survive[21]. In Steve Job's words ". . . it was one of the best decisions I ever made. The minute I dropped out I could stop taking the required classes that didn't interest me, and begin dropping in on the ones that looked interesting."[23]. A substantive part of Robinson's thesis explains how the traditional educational system is structured in an outdated learner process of "one size fits all" without paying important attention to student's interests. The system imposes stringent rules on students based on obsolete learning assumptions and conformity. Although critical theorists have raised this issue in the past, Robinson highlights it more emphatically.

Robinson points out that the motivation behind the current system is to organize students into arbitrary categories, packing them up like bars of soap, without reference to their individual talents.[24] Robinson's writings and videos explain about how people learn in different ways. The central problem is that "traditional teaching methods largely ignore the multidimensionality of experience, of the subject, of phenomena and of knowledge itself. As Robinson concludes, the result is often how only a small portion of students find themselves in a position where the information that is rigidly handed down to them can be grasped, and in a way where they manage to work through the restrictive and highly ideological confines of that information".[24] Robinson and his followers suggest that rather than sponsoring and encouraging the exploration of phenomena in open and divergent ways, students are subjected to rigid forms of education. Many of the old paradigms promote an authoritarian and controlling theory of education over an organic theory of divergent and free-flourishing education.[24]

Therefore while the old paradigms are driven toward conformity and standardization, Robinson suggests that we should be going the other way. Robinson is working out the details of identifying one's element or talent and then organically developing it. He states that "Finding your element is a personal quest"[21]. The main advice from Steve Jobs to students reaffirms the same theme[23]. Steve Jobs would also agree with Robinson's[22] principle #2: "You create your own life" (page 23).

One may argue that creating one's own life is not easy for many people who do not have adequate resources and opportunities. Robinson's philosophy of an autonomous, divergent and free-flourishing education wherein a student finds his or her element, nurtures it, and designs an educational experience based on their primary interest may very well work for the highly motivated, exceptionally talented and well prepared students who have had pre-college access to

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advanced educational experiences and exposure to a variety of career options through their parents, relatives, family friends, teachers, school counselors, college recruiters, older siblings, etc. For the vast majority of students, however, this ideal situation is far from reality. Far too many high school graduates are inadequately prepared for college. The problem is systemic and the numbers are staggering. For instance the California Community Colleges Student Success Task Force[25] found that "70 to 90 percent of first-time students who take an assessment test require remediation in English or math, or both." In the California State University (CSU) System, campuses have more than a third of incoming freshmen that are not prepared for college-level math.[26] In some campuses like CSU East Bay, over 70% of students are not prepared for college-level math.[27] For most of these students, especially those from underrepresented minority groups, navigating a "prescriptive" college educational experience is very challenging, and without the appropriate background, preparation, exposure, experience and support, designing their own educational experiences that would lead to success would be nearly impossible. As a result, adopting an educational system that is based on Robinson's philosophy could lead to an engineering profession that is even more exclusive and inaccessible than it already is.

The following table may help in order to contrast the traditional paradigms against the emerging paradigms in broad general terms, although confusion may arise from lack of explanatory details in the table form.

Table 1: Distinctive features of Traditional and Emerging Paradigms

	Traditional Paradigms	**Emerging Paradigms**
1	Students are vessels that need to be filled	Students develop their potentials & create themselves
2	Students memorize a lot of information	Students reason, relate & practice problem solving
3	Faculty provides direct instruction using lectures	Faculty facilitates & guides
4	Students acquire the same skill set achieving conformity	Each student develops his/her potentials giving rise to diversity
5	Facts, data & rules are emphasized	Creativity & uniqueness are emphasized
6	Students perform in exams & faculty evaluates & grades	Students solve problems & faculty provides feedback with formative assessments

In addition to the above contrast, a careful comparison among emerging paradigms is also necessary for assessing their relative merits and demerits. An educated skilled and diverse workforce is essential to world leadership and economic competitiveness. This is one of the reasons for monitoring the trends in emerging paradigms with great hope. One may also like to pay attention to some other trends[28-37] that are not discussed here.

Conclusion

It is difficult to make conclusive remarks about the emerging paradigms because these paradigms have not fully emerged yet. Some aspects of the emerging paradigms are still under

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development and contributions towards their development would be debated in the process. However, it is risky to ignore the emerging paradigms even if their merits are not entirely clear, because the economic competition cannot be won without an educated workforce with diversity of talents. Discussions about emerging paradigms and their social, political and academic ramifications should continue as these paradigms emerge and spread into practical environments if they are received well by the practitioners. Moreover, these discussions should be grounded in the context of current and future opportunities and challenges in engineering education including the rising cost of higher education, the increasingly interdisciplinary nature of the profession, the continued underrepresentation of women and minorities, the increasing number of nontraditional students pursuing degrees in engineering, and the growing percentage of students graduating high school inadequately prepared for college, a steady decline of ethical and moral values. In the meantime, the authors continue to monitor the developments of new trends and participate in the educational activities in their respective educational institutions. Hopefully public debates and discussions clarify issues through dialogs in addition to serious monologs. As we struggle to understand in the changing needs of the workplace, we need to consider how to modify educational systems in order to meet new workplace demands. Many different innovations are needed for making changes that are effective in the learning environments where increasingly more attention needs to be paid to diversity along with other factors. Many academic institutions are taking advantage of globalization and creating nurturing environments for ethnic, social, cultural and racial diversity.[iii]

Notes

i. One of the authors of this article has pointed out that a more recent study shows that U.S. students are doing better: “The U.S. did reasonably well in all three subjects-reading, math, and science. In reading, the U.S. scored 556 on the international scale. All of the tests discussed in this section have a mean of 500 and a standard deviation of 100. Only four countries scored statistically significantly higher on the reading test. (In the discussion below, the term “significant” is used as shorthand for statistical significance at p less than .05). Hong Kong led the world at 571, followed by the Russian Federation (568), Finland (568), and Singapore (567).”
   http://www.brookings.edu/research/reports/2013/03/18-timss-pirls-scores-loveless

   It was also indicated that a better measure would be to examine college graduation rates: “U.S. college graduation rates rank 19th out of 28 countries studied by the OECD, which tracks education investment and performance of wealthier democracies, said OECD Director for Education and Skills Andreas Schleicher.”
   http://www.oecd.org/edu/Education-at-a-Glance-2014.pdf

ii. The contribution of the Khan Academy delivery method towards the flipped-classroom approach is questionable as pointed out by one of the co-authors. That is, in the flipped-classroom approach, it is possible that the students may read notes instead of watching videos.

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iii. "While stuck in systems that seem to preclude identifying talent in robust ways, something must be in place to promote diversity." Daryl G. Smith American Journal of Education, August 2014, Page 599.

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Critical Thinking Pedagogy in Teaching Computer Hardware Design Course

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Abstract

The critical thinking skills are highly required in the engineering field nowadays due to the competitive world demanding complex problem solving skills from engineers. This paper presents the critical thinking pedagogy the author applied in teaching computer hardware design undergraduate course. In this work, undergraduate computer engineering students were divided into small groups of 3 to 4 students to participate in the technical paper reading, project proposing, design discussion, and design presentation. Students used schematic based CAD tools and also Verilog[1] Hardware Language based design tools to get engaged in the process of designing the computer hardware components such as the FIFO[2], and also the Mic-1[3] microprocessor. The organization of the design assignments applied in this course was to encourage students for hypothesis formulation, problem analysis, information synthesis, clear articulation of design ideas and results, and also draw logical conclusions, which are core skills for critical thinking. Students learning outcomes were clearly specified in the projects assigned which were designed according to the course learning outcomes. They were evaluated after student designs were collected and positive results were identified in this work.

1. Introduction

Critical thinking requires the ability to analyze and evaluate information[4, 5, 6]. A lot of researchers have recognized the importance of critical thinking in education. How to organize active learning environment to enhance critical thinking among students has been one challenging and also passionate topic for many educators. In the field of health science, case studies were used to promote critical thinking. Life experience case examples or simulated real patient situation cases were used by nurse educators to help students acquire critical thinking skills[7]. In the Introduction to Civil Engineering course, carefully designed reflective writing assignments were provided to students to stimulate critical thinking[8]. Moreover, business professors developed interactive thinking and discussion games to improve students' critical thinking skills[9]. In general, educators from different fields tried to use appropriate methodology to facilitate critical thinking based on different course contents.

Understanding the internal architecture of microcomputers is crucial for undergraduate students in the advancement of their study and work in the field of computer engineering. At California State University, Sacramento (CSUS), the Computer Hardware Design course is required upper division computer engineering undergraduate course. The computer hardware related textbooks typically had a lot of abstract context and described complex interaction of different digital signals inside the microcomputer. In general, undergraduate students had difficulty to visualize

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and analyze the behavior of the complex microcomputer system effectively by just passively memorizing information.

In this paper, critical thinking pedagogy in teaching computer hardware design course to undergraduate students in Computer Engineering at CSUS are presented. Part 2 describes using in class discussion to stimulate critical thinking among students. Part 3 discusses computer aided design to engage students on critical thinking. Part 4 presents using the group based open-ended project to improve critical thinking. Part 5 demonstrates the outcome of the presented pedagogy, and also discusses the assessment result and future improvement plan. Finally, part 6 draws conclusions of this work.

2. In Class Discussion to Help Critical Thinking

In order for students to develop critical thinking skills, in-class discussion can be used as one method to practice critical thinking.

Mic-1 processor is based on Von Neumann architecture which supports Integer Java Virtual Machine (IJVM) instruction set. To study Mic-1 processor, students were partitioned into groups and each group was given one different IVJR instruction. The instructor also selected one different IVJR instruction. Both students and instructor participated in the discussion of the functionality of the related micro-instructions stored in the control store inside classroom. The micro-instructions were used to control the microprocessor data path. In this way, students had to actively think and analyze the behavior of the Mic-1 microprocessor architecture. Different from the traditional instructor-centered teaching which required instructor to focus on transferring knowledge directly to students, students were required to join in-class discussion to stimulate critical thinking.

3. Critical Thinking though Computer Aided Design Tool

Logisim[10] is an open source free logic design tool. The author required students to design MIC-1 processor described in the textbook[3] by using Logisim. Computer aided design work allows students to visualize the behavior of computer hardware architecture in more concrete way and engage students in critical thinking. It makes learning more interesting and meaningful to students.

Mic-1 processor has two 32-bit data busses: B bus, and C bus. It also has a control store with micro instructions used for sequence controls. In addition, it has Arithmetic Logic Unit (ALU), shifter and multiple internal registers. This assignment has the following learning outcome.

- Apply logic concepts and mechanisms to design microprocessor components;
- Apply logic concepts and mechanisms to analyze microprocessor components;
- Formulate a specific hypothesis of microprocessor architecture. Thoroughly analyze the logic components required for microprocessor architecture. Carefully design and evaluate the functionality of each logic block;
- Use schematic based tool to design and conduct experiments, as well as to analyze and interpret data;

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- Three or four students form a group for discussion. Acknowledge the limits of the position and synthesize others' points of view in each group and draw logic design conclusions.

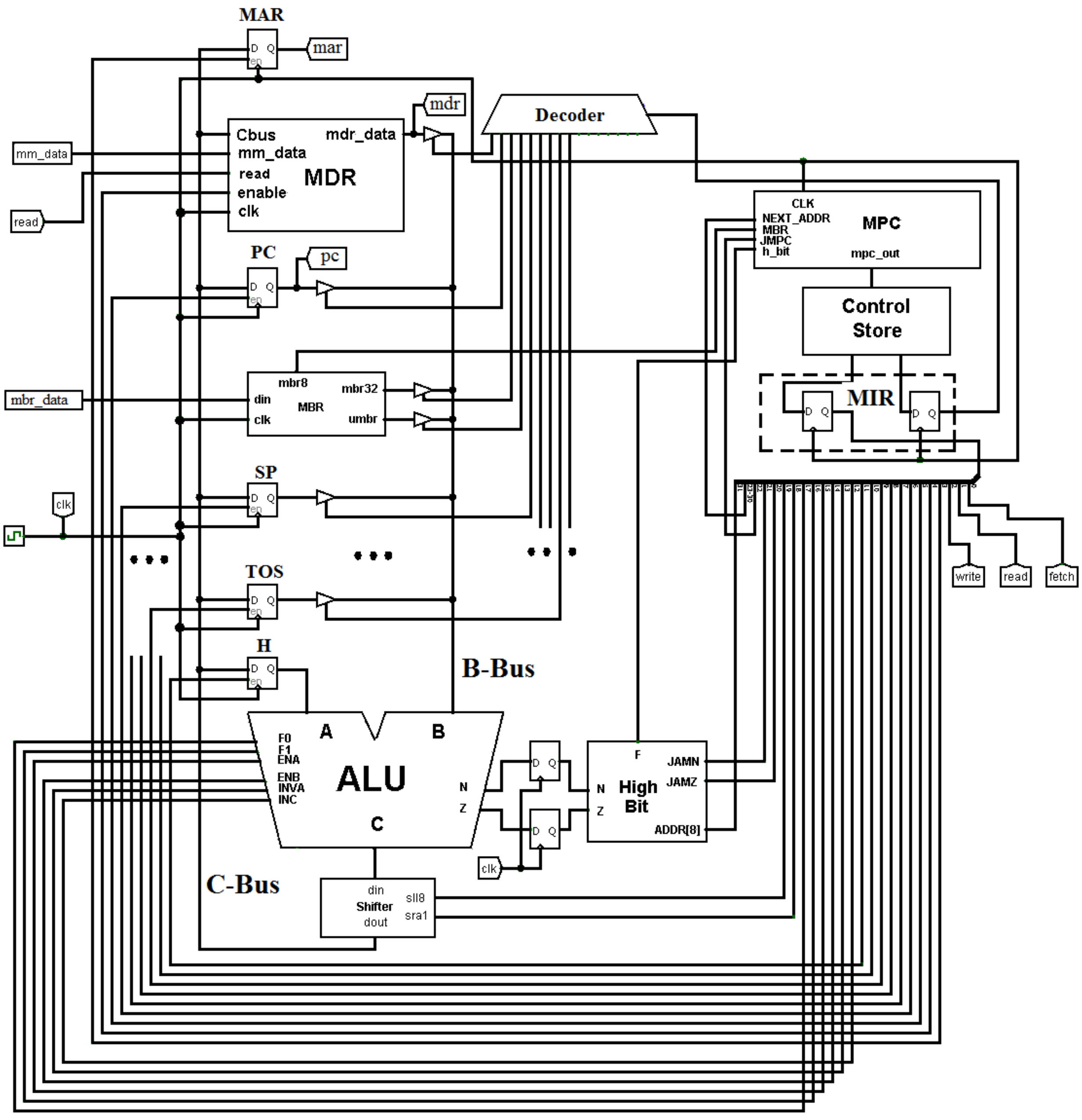

Figure 1. Logisim design of Mic-1 microprocessor

Figure 1 shows the Logisim design of Mic-1 processor. Although all registers used in Mic-1 were designed, in order to minimize the size of the circuit diagram, only part of registers are illustrated in Figure 1 which includes the memory address register MAR, the memory data register MDR, the program counter register PC, the memory buffer register MBR, the stack pointer register SP, the top of the stack register TOS, the holding register H, the micro-program

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counter register MPC and the micro-instruction register MIR. The size of MPC register is 9 bits. The register connected with the N-flag is 1-bit, and so does that connected with the Z-flag. The size of the MIR register is 36 bits. The MIR register in Figure 1 consists of two parts: 32-bit part and 4-bit part. All of the other registers are 32-bit long. The MDR register can input data from either the main memory or the C-Bus. The MBR register can output unsigned data “umbr” or sign-extended data “mbr32”. The shifter design supports no shift, logic left shift by 8 bits, and arithmetic right shift by 1 bit.

During Logisim simulation, the internal signals of “write”, “read”, “fetch”, “mar”, “mdr”, “pc” which are used to control the main memory can be monitored. The main memory stored data and instruction can be manually entered through ports “mm_data” and “mbr_data”. The clock signal of “clk” can also be monitored.

Logisim supports sub-circuit design strategy. 1-bit ALU logic circuit is given in textbook. By using 1-bit ALU sub-circuits, students can design 32-bit ALU circuit which has “N” (negative) flag and “Z” (zero) flag to indicate the ALU result is negative or zero.

The designed schematic of the High Bit sub-circuit used in Figure 1 is shown in Figure 2, where the signals of JAMN, JAMZ, and ADDR coming from the MIR register are used to control the highest bit of the next possible micro-instruction address location.

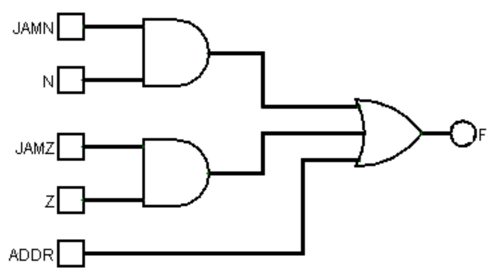

Figure 2. High Bit subcircuit

The 9th bit of the MPC register value is determined by the High Bit sub-circuit output. The lowest 8 bits of the MPC register value use “JMPC” signal from the MIR register to select the microinstruction address from either the MBR register value, or the next address field from the MIR register output.

The 4-to-16 decoder is a built-in component from Logisim. The Control Store sub-circuit uses Logisim built-in ROMs which can be loaded with micro-instruction sequence data. Figure 3 below shows the micro-instruction sequence stored inside Control Store to implement the IJVR “bipush” instruction. The equivalent hardware operations are also listed in Figure 3. In conclusion, the Mic-1 Logisim design work can stimulate students to think and analyze the logic components required by the microprocessor. Modification of this design is also possible which may stimulate students more for creative design ideas.

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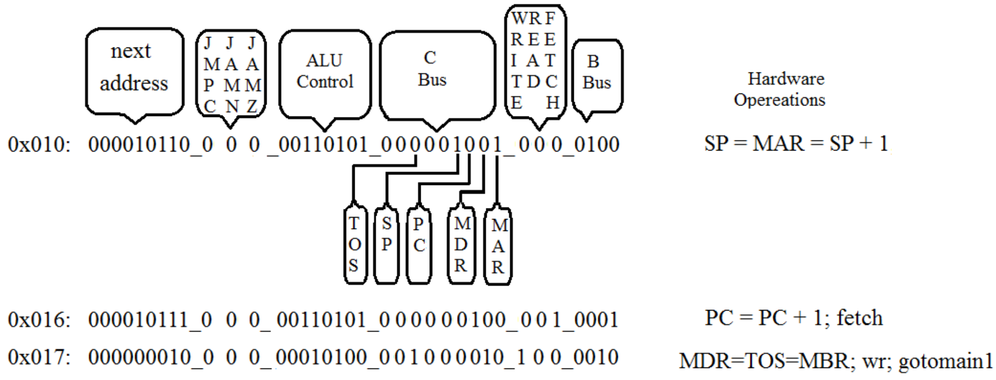

Figure 3. The Control Store micro-instruction sequence for IJVR "bipush" instruction

4. Critical Thinking through Open-Ended Project

The open-ended project is another method used by the author to stimulate student curiosity, to promote divergent thinking, and to enhance student critical thinking skill. FIFO is a memory buffer used for communication between two microprocessor components. The first data written into the FIFO will be the first data that is read out. The FIFO design was assigned by the author as one open-ended project through the following methods:

a. Instructor guidance;
b. Technical paper reading;
c. Pre-project presentation of the design proposal;
d. Design project in small groups;
e. Post-project presentation and discussion of the design result.

This assignment was to achieve the following outcome.

- Apply logic concepts and mechanisms to design microprocessor components;
- Apply logic concepts and mechanisms to analyze microprocessor components;
- Develop ability to identify interface signals and conduct a comprehensive analysis of FIFO circuit logic behavior;
- Formulate a specific hypothesis of FIFO architecture. Thoroughly analyze the FIFO design logic blocks. Carefully design and evaluate the functionality of each logic block;
- Use computer aided design tool to design and conduct experiments, as well as to analyze and interpret data;
- Three or four students form a group for discussion. Acknowledge the limits of the position and synthesize others' points of view in each group and draw logic design conclusions.

4.1 Initial Stimulation for Open-Ended Project

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For complex projects, students might feel too intimated to take the first try. As a result, proper guidance provided by the instructor is necessary to start the initial stimulation. In addition, group discussion and in-class discussion allow students to stimulate each other, and evaluate other people's views. So it is beneficial to partition students into small groups to facilitate learning. The instructor provided document to give students ideas about FIFO and also required students to read a FIFO technical document with FIFO signals and functionality[2]. However, students were allowed to come up with their own ideas of necessary FIFO block partitions, functionality of each block, interface signals of each block and prepare proposals. Students were also allowed to collect different technical documents for reading and use them as references.

4.2 Pre-project Presentation of Design Proposal

Inside classroom, each group was required to give presentation of their proposed FIFO design blocks, FIFO signals and functionality. In each group, every student must present part of the proposal.

Verbal presentation helps students organize their thoughts, clarify their thinking, plan their design work, analyze and evaluate different design options. Group based presentation also motivates students to work together. The guidance from the instructor is necessary to make sure the direction of the student proposed project work will be on a reasonable route for learning. After pre-project presentation, each group of students needed to conduct deeper thought and implement the proposed design work using computer aided tools. Instructor could be consulted if students had questions.

4.3 Post-project Presentation and Discussion of the Design Result

After students completed their design work, post-project presentation was required inside the classroom for students to explain and justify their design results. Both inside classroom discussion regarding the project work and after classroom further evaluation and suggestion from instructor were used as feedback to the design work.

Students from different groups used different methods for the FIFO design project. Figure 4 shows part of the FIFO simulation result from one group of students. This group of student used Verilog Hardware Description Language to design the FIFO.

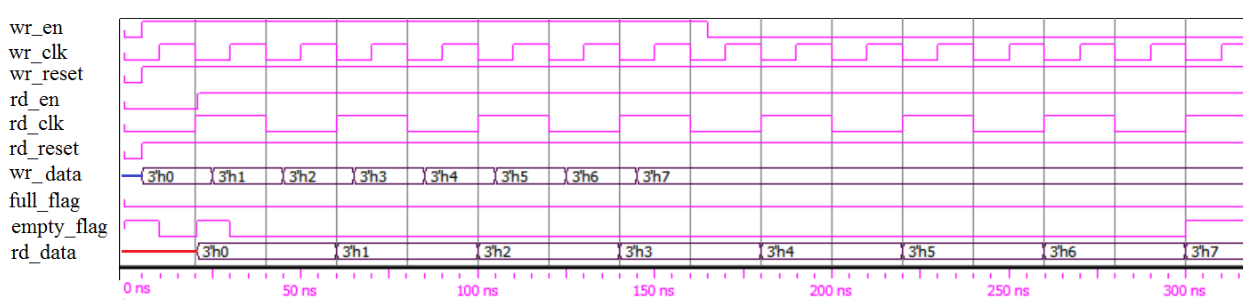

Figure 4. FIFO simulation waveform

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In Figure 4, the reset, enable, and clock signals used for FIFO writing are “wr_reset”, “wr_en”, and “wr_clk”. The similar signals used for FIFO reading are “rd_reset”, “rd_en”, and “rd_clk”. The data written into and the data read from the FIFO are “wr_data” and “rd_data”. At 0 ns, the FIFO doesn’t have data and the “empty_flag” signal is logic ‘1’. At time 10 ns, the first 3-bit data 3’h0 is written into the FIFO at the rising edge of the “wr_clk” and the FIFO is not empty. At time 20 ns, the data 3’h0 is read out of the FIFO, so the FIFO is empty again. Until at time 30 ns, new data 3’h1 is written into the FIFO, and the FIFO is again not empty. The “wr_clk” and “rd_clk” have different frequency. After the last data 3’h7 is read out of the FIFO, the FIFO outputs the active “empty_flag” signal again. The successful design result indicates that this group of students could improve their critical thinking and learning through the open-ended FIFO project.

Another group of students got strong interest in Logisim circuit design tool. They designed working FIFO sub-circuits shown in Figures 5, 6, and 7 using Logisim tool. Figures 5 and 6 show the FIFO read pointer and write pointer sub-circuits.

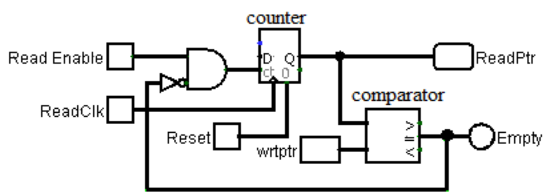

Figure 5. FIFO read pointer sub-circuit

In Figure 5, the counter circuit is a Logisim built-in component with reset, clock, and enable control signals: “Reset”, “ReadClk”, “Read Enable”. The counter output is used as FIFO read address pointer “ReadPtr”. The read pointer is synchronized with the “ReadClk”. If this read pointer value is equal to the write pointer “wrtptr” value, the “Empty” output from the comparator circuit will output logic ‘1’.

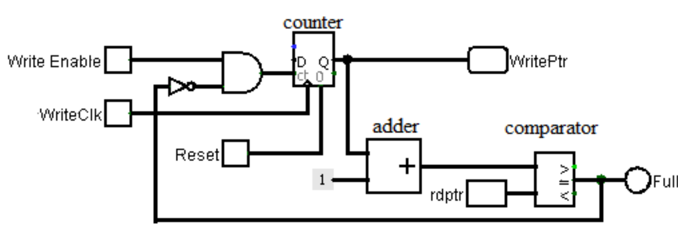

Figure 6. FIFO write pointer sub-circuit

Figure 6 uses the similar strategy as that in Figure 5. The FIFO write pointer “WritePtr” is synchronized with the “WriteClk”. If “WritePtr” value is increased by 1, and the result is equal to the read pointer “rdptr” value, the comparator output “Full” will be equal to logic ‘1’.

Figure 7 shows the 8x4 memory sub-circuit design consisting of D Flip-flops and decoder components. This memory circuit has 3-bit address inputs “addr” and 4-bit data inputs input0 ~ input3Moreover, it has reset, chip select, read/write, and output enable control signals: “Reset”, “cs”, “rd”, and “oe”. Since this design only allows either data writing or reading at a particular

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time, it cannot support two different writing address pointer and reading address pointer at the same time. However, the exploration of students on this logic memory circuit design is still useful to stimulate them to think the behavior of memory circuit and the limitation of this work.

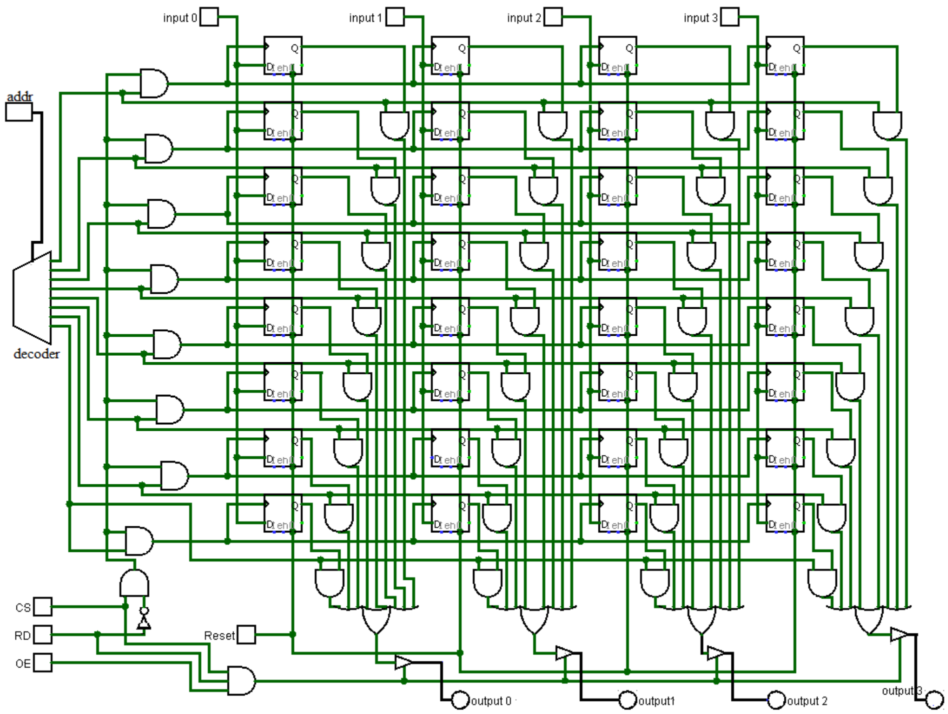

Figure 7. 8x4 memory sub-circuit

The final top level design from this group of students was not correct due to the limitation of their memory sub-circuit design mentioned above. However, multiple working sub-circuit design showed that this group of students got involved with deep thinking, analysis and synthesis of the logic level computer circuit components.

5. Outcome and Future Improvement

The author developed critical thinking method for teaching computer hardware design course according to the guideline from Association of American Colleges and Universities (AACU) [11] Critical Thinking VALUE Rubric. Students commented that they enjoyed working in small group discussion on course materials and they thought it was beneficial for learning with student-centered critical thinking and active learning approach.

The key advantages of the implemented critical thinking pedagogy in teaching computer hardware Design Course are shown below.

i. Help students gain confidence to read technical papers and to explore new information.
ii. Motivate students to use computer aided design tools to sharp their critical thinking.
iii. Assist students to develop critical thinking skills through small group based learning.
iv. Encourage students to express ideas, participate in group based learning, and improve critical thinking skills.

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The rubric shown in Table 1 was adapted from the AACU VALUE Rubrics for critical thinking on a scale from 1 to 4. 10 student samples from 3 different groups in the computer hardware design course at CSUS were evaluated for critical thinking for the semester of fall 2014. Students voluntarily formed their own groups in the beginning of the semester. Only 3 or 4 students were allowed to be in one group. Group A had 3 students, group B had 3 students, and group C had 4 students. In the beginning of the semester, the instructor organized in-class discussion. However, only one student was able to participate in class discussion. All the other 9 students were quiet and seemed to be more comfortable with passive learning. The instructor organized critical thinking pedagogy in teaching for the whole semester. At the end of the semester, the students were assessed again for critical thinking. The assessment result is shown in Table 1.

Table 1. Student Assessment Data for Critical Thinking

SKILLS	4	3.5	3	2.5	2	1.5	1
Explanation of issues		30%	20%	20%	10%		20%
Evidence (Selecting and using information to investigate a point of view or conclusion)		40%	10%	30%			20%
Influence of context and assumptions		30%	20%	20%	10%	20%	
Student's position (perspective, thesis/hypothesis)		30%	10%	30%	10%		20%
Conclusions and related outcomes (implications and consequences)		40%	20%	10%	20%		10%

The instructor found out later that every group had 1 good learner. Groups A and B had good learners and ordinary learners. Those students in groups A and B learnt well in the group-based setting, and stimulated each other to improve critical thinking skills. Unfortunately, group 4 had 1 good learner, and 3 slow learners including students D, E and F. Student D was a slow learner, at the same time he was quiet and not active in participating in group discussion. Student E was a slow learner, he had conflicting schedule with other students, so he only participated in group discussion slightly. Both student D and student E enjoyed presentation in either group setting or in individual setting with their own proposed topics. Student F was slow learner, however he was willing to participate in active discussion with the good learner in his group and they could still stimulate each other. However, two slow and inactive learners negatively affected the attitudes of the other two active students somehow in this group. Such classroom observation matches the Table 1 assessment result.

In the future, the author plans to improve the critical thinking pedagogy by doing the following:

- Monitor the group forming process by the instructor to make sure group members are diverse in ability levels and also they have common meeting time outside class.
- Design small warm-up exercises to break down big task for slow learners.

Conclusion

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Small group based learning has demonstrated learning benefit to enhance student critical thinking skills and engage students in active learning in computer hardware design course. Moreover, organizing diversified group study styles is beneficial to motivate critical thinking and active learning including in-class discussion, after-class discussion, presentations, project work and so on. Moreover, computer aided tools can help students visualize complex problems and stimulate critical thinking. Open-ended project can also be used to further improve critical thinking. In the future, the author plans to monitor the effective group forming process and also design smaller size warm-up exercises to help slow learners.

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Engaging Community College Students in Earthquake Engineering Research on Real-Time Hybrid Simulation

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Abstract

Community colleges serve as the gateway to higher education in the United States. Engaging community college students in engineering studies especially earthquake engineering research is of significant interests for the San Francisco Bay Area and the state of California. Future earthquake disaster prevention and preparation require that professional civil engineers are trained and recruited into the next generation workforce for the purpose of public safety. With support from NASA through the Curriculum Improvement and Partnership Awards for the Integration of Research (CIPAIR) program, four community college engineering students participated in a ten-week summer research internship program at San Francisco State University in summer 2014. The project focuses on an innovative experimental technique of real-time hybrid simulation for earthquake engineering research. The purpose of the project is to evaluate the effects of delay on real-time hybrid simulation and to apply a probabilistic approach for reliability assessment. MATLAB and Simulink are used and probabilistic concepts are applied to account for characteristics of one hundred ground motions. This research internship program allows for the development of project management, time management and teamwork skills, thus helping strengthen students' knowledge of seismic design in civil engineering and prepare them for successful academic and professional careers. The internship program therefore provides valuable mentorship for community college students during their transition to a four-year college and their decision to pursue a civil engineering profession.

1. Introduction

Recent earthquakes in California and Japan have caused significant impact on human society (20 killed, $20B in direct losses during the 1994 Northridge earthquake, and 5500 killed, $147B in direct losses during the 1995 Kobe earthquake). Similar earthquakes of magnitude 6.0 or greater can have a more profound impact on the greater San Francisco Bay Area. Future earthquake disaster prevention and preparation require that young professional civil engineers be trained and recruited into the next generation workforce as part of the efforts to mitigate seismic hazard and improve public safety.

Community colleges serve as the gateway to higher education for large numbers of students especially in California. The California Community College System, with its 112 community colleges and 71-off campus centers enrolling approximately 2.6 million students is in a prime

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position to grow the future STEM workforce [1]. However, for science and engineering fields, lower success and retention rates are observed at both community college and university levels resulting in underrepresentation of minority groups in these fields. Cañada College is a member of the California Community College System, and is one of three colleges in the San Mateo County Community College District. It is one of only two federally-designated Hispanic Serving Institutions in the San Francisco Bay Area. San Francisco State University is a large, regional, comprehensive university, part of the California State University System. In fall 2009, 30,469 students enrolled at SFSU: 25,001 undergraduates and 5,468 graduate students. Students pursue 115 undergraduate majors, 97 master's degree programs, 27 credential programs, and 37 undergraduate and graduate certificate programs. Funded by NASA through the Curriculum Improvement and Partnership Awards for the Integration of Research (CIPAIR) program, Cañada College's Creating Opportunities for Minorities in Engineering and Technology (COMETS) program attempts to address some of these barriers to the successful transfer of community college engineering students to a four-year institution including inadequate preparation for college-level courses, especially in mathematics, low success rates in foundational math courses, lack of practical context in the traditional engineering curriculum, and inadequate relevant internship opportunities for lower-division engineering students. The project aims to maximize the likelihood of success among underrepresented and educationally disadvantaged students interested in pursuing careers in STEM fields by incorporating strategies that address challenges and barriers to recruitment, retention and success of these students. Among the strategies developed for this project is a ten-week summer research internship program developed collaboratively with San Francisco State University, a large comprehensive urban university in San Francisco. The goals of the program are to strengthen students' identity as engineers and researchers; increase student interest to further engage in research activities; and enhance student self-efficacy for successfully transferring to a four-year university, completing a baccalaureate degree in engineering, and pursuing a graduate degree.

2. **Civil Engineering Project**

Shake table, quasi-static, and hybrid simulation tests are the three main experimental methods that are used in laboratory on the seismic performance of structural systems. Although the most accepted seismic testing method, high cost and scaling problems make shake table test a difficult experimental method for structural system analysis. On the other hand, although lower in cost, static experiments, such as quasi-static tests, create certain uncertainty about the results. On the other hand, real-time hybrid simulation is a cost-effective dynamic method which is could be used for large scale testing as well [2-3]. The schematic representation of real-time hybrid simulation is shown in Figure 1. The actuators have intrinsic delay to the command due to servo-hydraulic dynamics. This delay, even though in millisecond (ms) magnitude, could significantly affect the experimental results from real-time hybrid simulation. It is therefore necessary to have actuator delay compensation to achieve reliable RTHS results. However, experimental studies have indicated that the most sophisticated compensation method cannot completely eliminate actuator delay induced tracking error [4-5]. It is therefore important to evaluate the effect of delay on the accuracy of real-time hybrid simulation.

A team of four Cañada College students conducted summer research for the NASA CIPAIR Program at San Francisco State University. The main focus on the project is the evaluation of the effects of actuator delay in the accuracy of the real-time hybrid simulation results. MATLAB and

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Simulink are used to for numerical simulation and numerical calculation. The model parameters are 100 different ground motions, which 44 are Far-Field and 56 are Near-Field [6]. The research focuses on the single-degree-of-freedom (SDOF) structure, of which the equation of motion can be expressed as

$$m\ddot{x}(t) + c\dot{x}(t) + r_a(t) + r_e(t) = m\ddot{x}_g(t) \tag{1a}$$

where m and c are the mass and the inherent viscous damping of the SDOF structure, respectively; r_a and r_e are the restoring forces of the analytical and experimental substructure, respectively; $\ddot{x}_g$ is the selected ground motion for the real-time hybrid simulation. When the SDOF structure behaves linear elastic, the restoring forces can be calculated as $k_a x$ and $k_e x$, respectively, where k_a and k_e are the linear elastic stiffness of the analytical and experimental substructure, respectively. When a delay τ exists in the servo-hydraulic actuator attached to the experimental substructure, the equation of motion in Eq. (1a) can be modified as

$$m\ddot{x}(t) + c\dot{x}(t) + r_a(t) + r_e(t-\tau) = m\ddot{x}_g(t) \tag{1b}$$

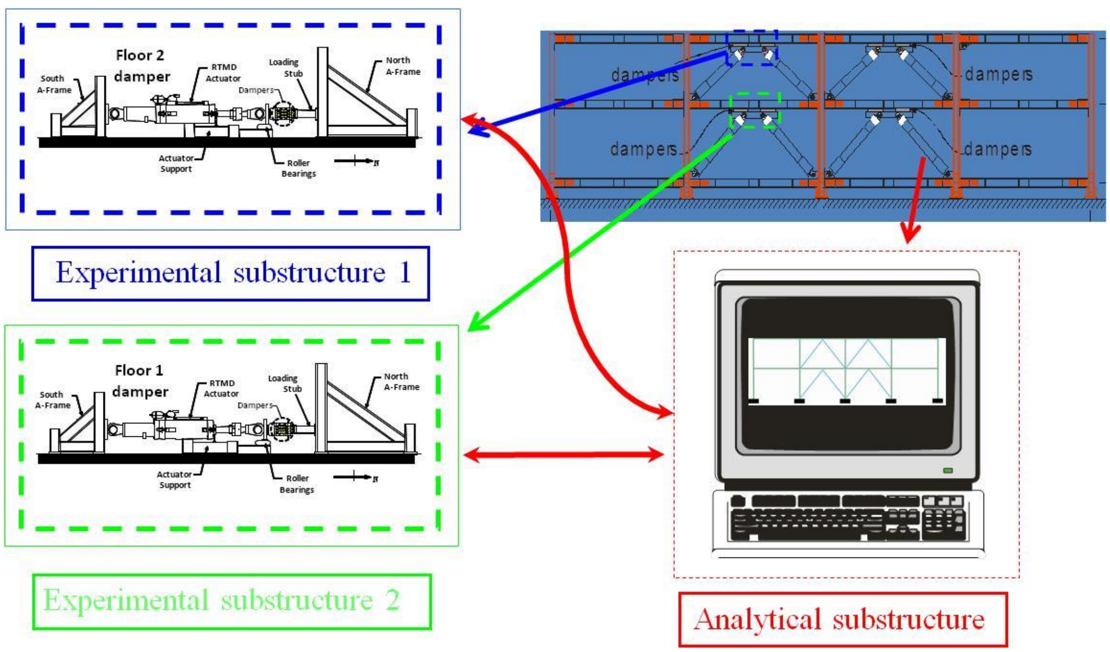

Figure 1: Schematic of RTHS for a Moment Resisting Frame with Energy Dissipation Devices

In order to replicate the nonlinear behavior of structures near collapse, the generalized Bouc-Wen model is utilized in this study. Figures 2(a) and 2(b) presents the hysteresis shape of a SDOF structure using the generalized Bouc-Wen model [7], respectively.

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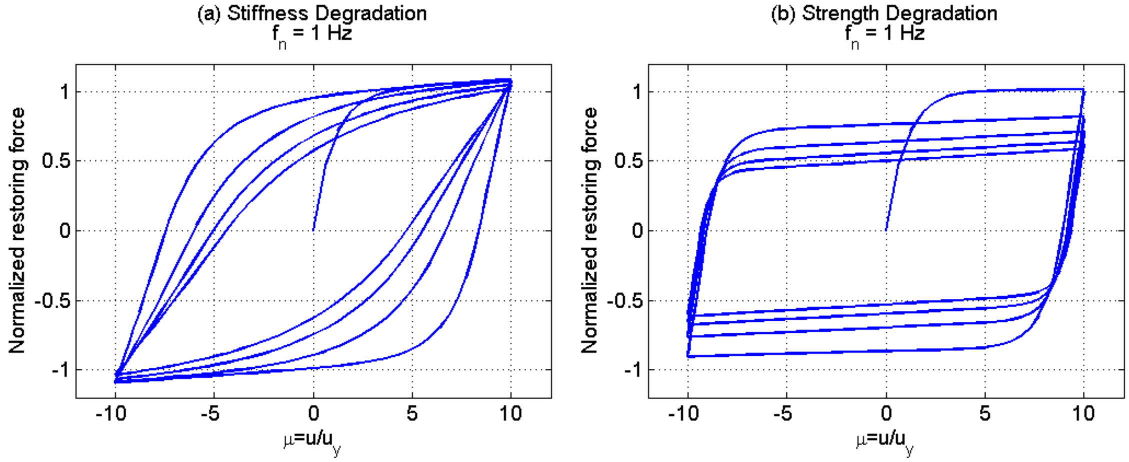

Figure 2. Hysteretic behavior using the generalized Bouc-Wen Model

For the CiPair program, the experimental substructure is 25% of total stiffness. The natural frequencies of the structure that are going to be analyzed are 0.25 Hz and 1 Hz. Both stiffness and strength degradation are considered. The time delay ranges from zero to 38 milliseconds with an increment of 2 milliseconds. A total of 24,000 cases were studied.

The MAX error is the accuracy index used in this study to compare the exact and delayed displacements and to quantify the error. MAX Error is dependent on the maximum exact displacement (X_c) and delayed displacement (X_m) and is calculated according to the formula below:

$$\text{MAX Error\%} = \frac{\max(|X_c - X_m|)}{\max(|X_c|)} * 100\% \tag{2}$$

3. **Student Project Outcomes**

After ten weeks of work, the civil engineering team accomplished the research objective. The following presents representative project outcomes. Figure 3 presents MAX Error with respect to delay for strength degradation. It can be observed that for a given scale and delay value, the quantity of MAX error increases with the level of degradation. However, for all degradation cases, MAX Error decreased with increasing stiffness for a given value of delay. These results are important because they indicates that when experimenting with near-collapse structural behavior where the structure is going through stiffness degradation, the effects of delay are more detrimental thus we need to make sure that the delay is small enough to receive reliable results

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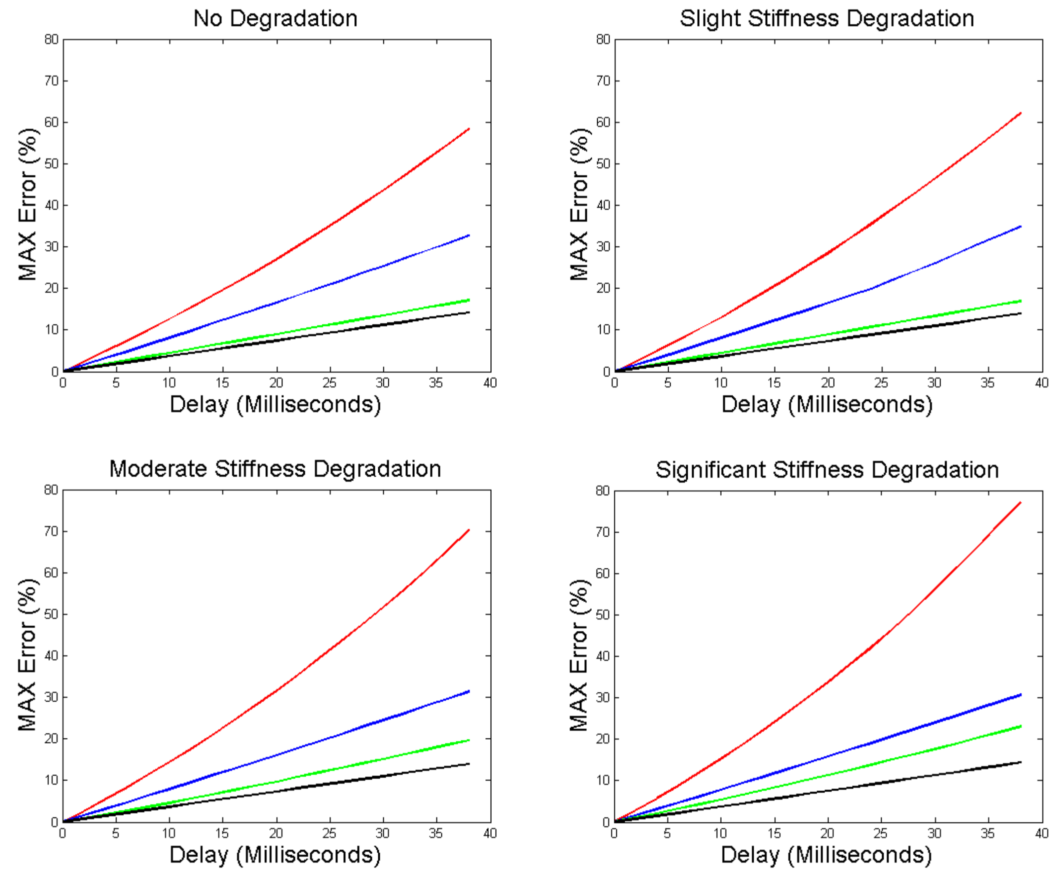
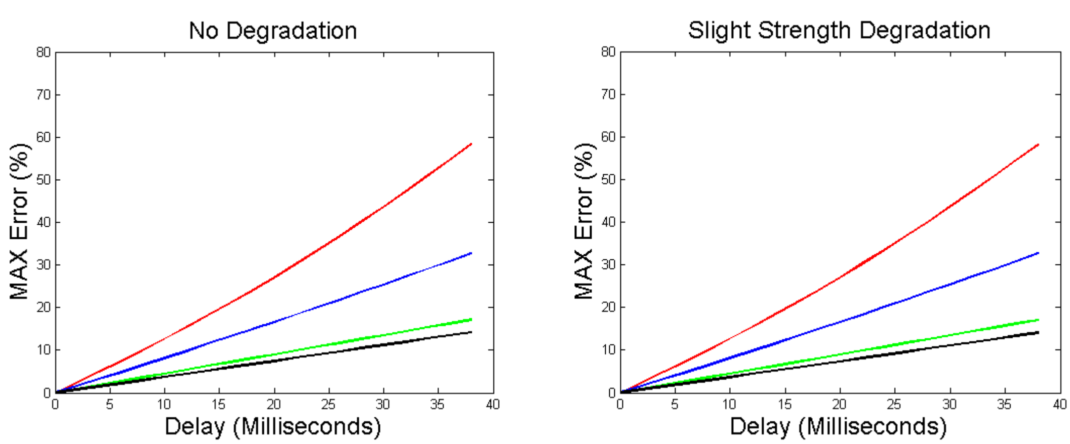


Figure 3. Comparison of MAX error for stiffness degradation

Figures 4 presents MAX Error with respective to stiffness degradation. It can be observed that for a given scale and delay value, the quantity of MAX error doesn't change with the level of degradation. All the figures are almost identical and just as in the case of the stiffness degradation, MAX Error decreases with increasing scale for a given value of delay. Therefore, strength degradation of a building near collapse does not affect MAX Error.



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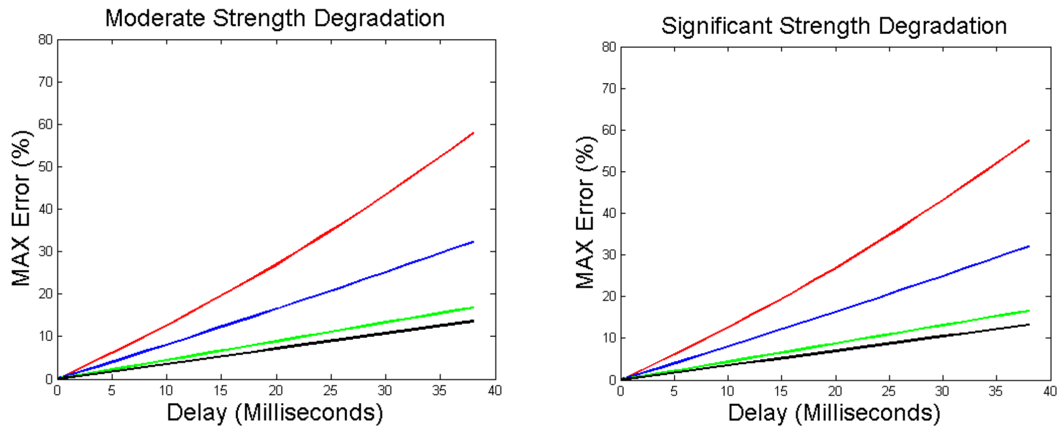

Figure 4. Comparison of MAX error for strength degradation

In addition to the computational simulation, the civil engineering team also conducted statistical analysis of the collected data. Figure 5 presents the results for a 10% target value. Figure 5a displays the histogram along with the fitted lognormal distribution and Figure 5b displays the quantile-quantile plot which is a measure for goodness of fit.

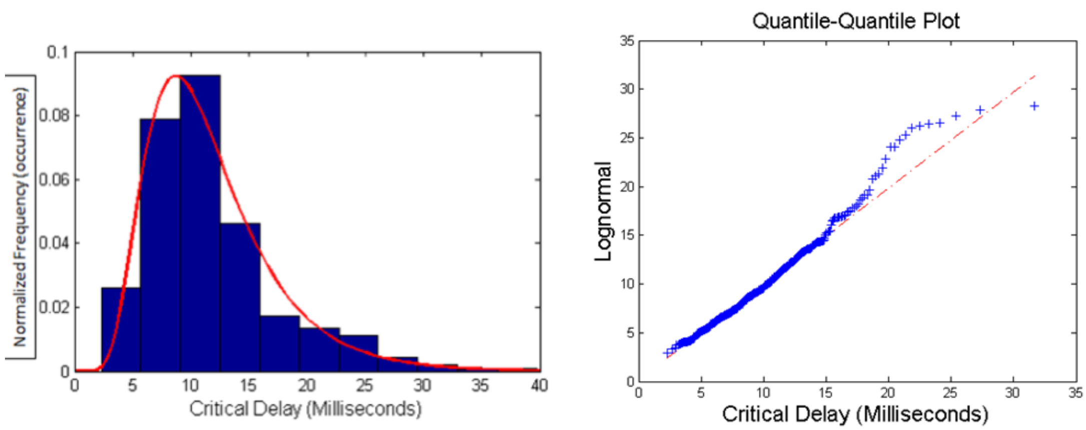

Figure 5. Statistical analysis of critical delay with respect to target error

4. **Project Outcomes Assessment**

To obtain a quantitative assessment of the project and further improve the project in the future, an exit survey was conducted for the four students participating the CiPair program including another twelve students in the mechanical, computer and electrical engineering research groups. Students were asked to rate their level of agreement with each question in a five-point scale: 1 – Not at all useful; 2 – A little; 3 – Some; 4 – Quite a bit; 5 – A lot. The tables below present the students' response to the survey questions. The survey was conducted anonymously to encourage candid responses to the survey.

Question: How useful were each of the following activities during your internship?
Response Scale: 1 – Not at all useful; 2 – A little; 3 – Some; 4 – Quite a bit; 5 – A lot.

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Activity	2014
Opening Day at SFSU	4.50
Faculty Adviser Description of Project	4.75
Meetings with Graduate Student Mentor	4.88
Meetings with Faculty Adviser	4.40
Weekly Progress Reports	3.93
Mid-Program Presentations	4.50
Final Presentations at SFSU	4.69

Question: As a result of your participation in the program, how much did you learn about each of the following?

Activity	2014
Performing research	4.31
Designing/performing an experiment	4.50
Creating a work plan	4.69
Working as a part of a team	4.56
Writing a technical report	4.50
Creating a poster presentation	4.63
Making an oral presentation	4.50

Question: Tell us how much you agree with each of the following statements.

Activity	2014
The internship program was useful.	4.56
I believe that I have the academic background and skills needed for the project.	4.44
The program has helped me prepare for transfer.	4.19
The program has helped me solidify my choice of major.	4.19
The program has helped me solidify my choice of transfer university.	3.56
As a result of the program, I am more likely to consider graduate school.	3.81
As a result of the program, I am more likely to apply for other internships.	4.75
I am satisfied with the NASA CIPAIR Internship Program.	3.75
I would recommend this internship program to a friend.	4.56

When asked the question "what do you like most about the NASA CIPAIR Internship Program?' Typical response from the civil engineering group students are: "*I liked how we got to work together and work with the mentor alongside in learning what they are doing*", "*What I like most about the NASA CIPAIR Internship program was that we were able to both work at NASA and at SFSU. I think that it was a great experience of going to SFSU*", "*I just liked the experience of internship. In my case, I had a perspective of civil engineering, but having to actually experience the research part was great. I liked that I was able to communicate with our mentors and see what further knowledge can make us do*."

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5. Summary and Conclusion

In this research project, the effects of actuator delay on real-time hybrid simulation are evaluated. Programs MATLAB and Simulink were used to run simulations of ground motions selected by FEMA P695. MAX Error was calculated for different delay values, scales, natural frequencies, and degradation cases. In experimenting with these different parameters results were evaluated showing how the parameters affect MAX Error. It could generally be said that the MAX Error will decrease with higher scales, MAX Error will increase with stiffness degradations at a higher rate compared to strengths degradations which will experience small changes in error over the same given time delay. Frequency of a structure will affect the MAX Error as well and a higher natural frequency will cause a higher MAX Error. These studies are focused to improve the understanding of real-time hybrid simulation results and plan better experiments. Therefore, they help experiments to be run at a much more cost efficient rate than doing tastings alternatives to real-time hybrid simulation testing. This research project was a learning experience in enhancing collaboration, organization, time management, and technical writing skills.

The CIPAIR program was very successful in creating opportunities for community college students to engage in advanced academic work that develops research skills and applies concepts and theories learned from their coursework to real-world problems. The program has also helped students in solidifying their choice of major, improving preparation for transfer, enhancing student self-efficacy in pursuing careers and advanced degrees in engineering, and acquiring knowledge and skills needed to succeed in a four-year engineering program. The program has also provided context to their study of engineering – a strategy that has been proven to increase student motivation and persistence – especially as they struggle through the first two years of the engineering curriculum.

Acknowledgements

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Teaching Machine Design Using HILTI Machine Tools Industry/University Collaborative Project

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Abstract

This paper presents the results of a case-study using a local industry sponsored research project at an undergraduate based polytechnic university to support capstone design experiential learning. The case study from HILTI Machine Tools demonstrates how engineering companies can realize cost effective research and development by mentoring and sponsoring an engineering undergraduate curriculum in the form of capstone design projects. This paper shares the results of the HILTI sponsored project for the ME 325 "Machine Design" course at Cal Poly Pomona, which is a junior level design course at Cal Poly Pomona in the Mechanical Engineering Department in the design curriculum. The design curriculum in Mechanical Engineering at Cal Poly Pomona is comprised of the following sequence of courses ME 233/L "Intro. to Mechanical Design/Lab", ME 319 "Stress Analysis", ME 325/L "Machine Design/Lab", ME 425/L "Advanced Machine Design/Lab", and ME 421 "Dynamics of Machinery". The HILTI company was represented by a team of three engineers who acted as mentors to the students in the ME 325 course. The HILTI mentors devised a "sitfler" problem whereby the teams of undergraduate students were required to develop an engineering solution following a systems engineering framework. The students worked closely with the industry mentors and utilized their knowledge of machine design, mechanism design, dynamics, materials, economics, engineering graphics, ease-of-fabrication, realism, etc., in order to realize a cost effective engineering solution base on customer requirements. The particular problem used by HILTI was the re-design of a Cold Press Tool and Die Mechanism. The project involved the feeding of a metallic powder at a certain rate. This paper documents the use of field-trip-based industry projects to motivate experiential learning at a polytechnic university. The various stakeholders in these type of endeavors involve the students, the engineering companies, the local community, as well as the faculty. Assessment tools and grading rubrics used to quantify the student experiential learning are also discussed.

Introduction

The use of engineering capstone projects for undergraduate engineering education is common in the literature. The study of Gannod *et al.*[1] presents the concept that a capstone course is meant to provide graduating seniors with a culminating experience that ties together the knowledge and skills that have been attained over the duration of a four-year curriculum. In the study of Conn and Sharpe[2], the authors describe a year-long senior mechanical engineering design course that is run in cooperation with industry. Financial support from an industrial sponsor, along with regular contact between the industry representative and the student groups, presents a real-world setting for the course. Students must learn to work together to order from outside vendors, stay within a budget, and prepare for presentations. The Engineering Design

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Project gives about-to-graduate engineering students an experience which is, in an academic environment, as close as possible to the realities of how project engineering is practiced in an industrial or government organization. Because the class size is small, all students are able to at least vicariously share in the wide range of experiences. The investigation of Paretti and Burgoyne[3] presents the results of a two-year study of capstone design courses which helps students treat communication activities as a critical element of professional engineering practice. The work of Hylton[4] compares and contrasts four different approaches; (i) traditional, (ii) design and build, (iii) on-line lecture, and (iv) the one-week intensive method for conducting a capstone design course and examines how the students seem to learn best and what motivates them to perform at the highest levels. Instructor and student perceptions are measured using assessment instruments as well as subjective observations. The study of Mirzamoghadam and Harding[5] outline the success story of capstone design project that partners an industry sponsor with a interdisciplinary engineering student team, whereby each industrial participant contributes a preset budget defined thus promoting the request for proposal (RFP) means of program sponsorship. In the work of Morgan *et al.*[6] feedback from industry and faculty experiences in product development led to a rigorous product development process in capstone design projects. As detailed in Morgan *et al.*[6] the process starts with a customer, followed by system requirements derivation, a feasibility study, a creation of test matrix and test plans, followed by preliminary design review (PDR), a critical design review (CDR), design and testing of components and subsystems, fabrication of working prototypes, and validation of system requirements. In the study of Morgan *et al.*[6], various project management tools are used during the process. Soft skills such as teamwork, presentation skills, writing skills, and ability to deal with ambiguity are emphasized throughout the capstone projects. The objective of the two semester capstone project experience outlined in Morgan *et al.*[6] is to better prepare the students for the real-world challenges they will face after graduation.

Other such success stories in pairing private industry with capstone design teams are found in the work of Tobar *et al.*[7] and Mertz[8] where Electrical and Computer Engineering projects are discussed. The main objectives of Tobar *et al.*[7] are to build up and reinforce skills fostered during a computer-engineering curriculum where the capstone project is the vehicle by which the student, the advisor and the client work together to realize a solution to a real-world technical challenge. In the work of Mertz[8] entrepreneurial soft skills are honed by the students who, while studying design alternatives, select a design responsive to a request for proposal and subsequently “sell” the design concept to a panel of independent evaluators with a written proposal and oral presentations. Capstone experiential learning activities such as that of Mertz[8] allow students to obtain experience in design within a cooperating group and completely fabricate and document a working electronic system. The course is intended not only to provide a meaningful design experience but also to accomplish a confidence-building transition to the role of a practicing engineer. A similar experience is outlined in Slivovsky and Slivovsky[9] where teams of computer engineering students deal with a real customer and are expected to do a significant amount of independent learning during their own time. In the study of Slivovsky and Slivovsky[9] students engage in a substantial amount of independent learning and are expected to become experts in their assigned topic and disseminate their knowledge with other members of their project team. Weekly oral presentations and a technical paper are primary deliverables of the projects of Slivovsky and Slivovsky[9]. Other

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success stories of capstone projects include the paper by Bachnak[10] where it is emphasized that capstone design courses provide students with the opportunity to use their problem solving skills and the technical knowledge they gain throughout their college experience to develop a device or system that meets some specific requirements. The use of engineering student design competitions which frequently require industrial sponsorship is discussed in the work of Klorbotly and Al-Olimat[11].

In the sector of Machine Design Education, Durfee[12] observes that design curricula in departments of Mechanical Engineering should provide students with an exposure to systems that incorporate embedded processors, real-time software, sensors and actuators. A graduate-level, project-based design course taught at MIT is described as one model for such an experience. The challenges in developing such courses are to channel student energy into a successful learning experience and to manage the high costs of student and instructor time, equipment and supplies. Based on an analysis of what abilities an engineer should have, some reforms to the teaching (contents and activities) of mechanism and machine theory (MMT) are presented in Jin *et al.*[13]. The new approaches aim to develop students' abilities in engineering design, including the ability to apply basic knowledge of science to engineering design, the ability to design and carry out experiments, the ability to make some engineering designs under realistic constraints, the ability to communicate effectively and function in a design team, the ability to use modern engineering tools, and the ability to identify and formulate an engineering problem. The outcomes of the reforms are also presented in Jin *et al.*[13]. In the work of Seif[14], design case studies developed through the National Science Foundation (NSF) Coalition, SYNTHESIS, to initiate systemic reform of undergraduate engineering education are presented. The extensive case studies given in Seif[14] cover all aspects of the life cycle of selected engineered products in which exemplary design practices have been followed. In Seif[14], the authors provide useful examples of design synthesis, interplay between technical and societal factors, industrial practice, multiple engineering disciplines and business considerations. Moreover, the work of Seif[14] provides a variety of design experiences, illustrate examples of good and bad engineering, and offer an opportunity to raise questions and discuss solutions. Study issues in reliability, maintenance, marketing, and design for easy assembly and manufacturing are highlighted in Seif[14]. More recently the work of Yoshiba *et al.*[15] Anderson *et al.*[16] and Anderson *et al.*[17] demonstrate how real-world industry problems can be used as a synthesizing agency as was used in the ME 425/L "Advanced Machine Design/Lab" course, where the lecture was team taught by industry mentors and a tenured university faculty member and a real world problem was used as the course system engineering based project.

In the literature survey above, it has been identified that the use of industry sponsored capstone design projects in engineering curriculum is a warranted and proven means of preparing future engineers to enter the workforce. This paper will document the use of field trip based industry projects to motivate experiential learning at a polytechnic university. The various stakeholders in these type of endeavors involve the students, the engineering companies, the local community, as well as the faculty. By utilizing the resources of upper division engineering students who are in the last year of their graduation, companies can tap the potential of having students work on 'stifler' problems at a much reduced investment cost. The university can be viewed as a pool of engineering services which is sustained by its own internal infrastructure and cutting-edge IT toolsets. To this end, the university offers an attractive alternative to

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companies seeking development work to be carried out at substantially reduced costs and associated risks than would normally be available. By utilizing the resources of upper division engineering students who are in the last year of their graduation, companies can tap the potential of having students work on 'stifler' problems at a much reduced investment cost. In this vein, the university can be viewed as a "pool" of engineering services which is sustained by its own internal infrastructure and cutting-edge toolsets and software products.

HILTI Case Study

The sponsor of the case study in this paper was the HILTI Corporation based in Cypress, CA that develops, manufactures, and markets products for the construction, building maintenance, and mining industries, primarily to the professional end-user. HILTI Cypress concentrates primarily on saw blades for cutting concrete. The paradigm used in the case study given here followed the systems engineering models of Aslaksen and Belcher[18] and Westerman[19] to allow the student teams to manage the problem given to them by HILT. The educational paradigm of project management of the industry sponsored case study discussed herein is derived from the System's Engineering V-Chart Shown below in Figure 1. Figure 1 was the basis for the brain-storming process in the case study discussed herein.

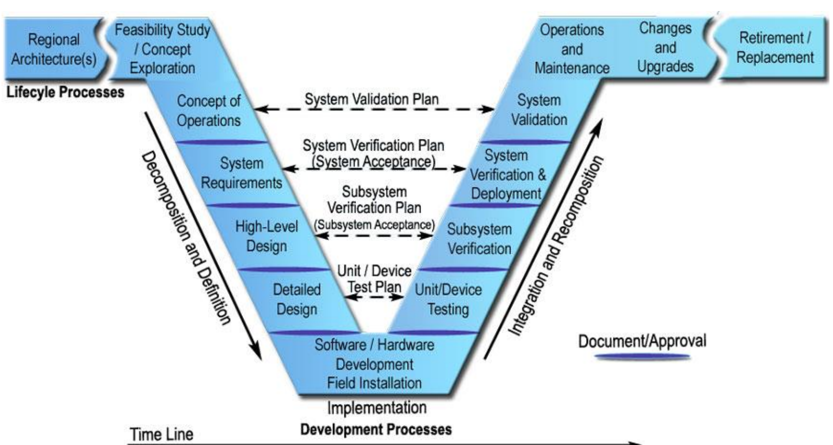

Figure 1 – Systems Engineering "V" Diagram cf. http://ops.fhwa.dot.gov/publications/seitsguide/section3.htm

The concepts of project design reviews (preliminary design review PDR, customer design review CDR) kick-off, feasibility studies, iterative design, documentation, integration and development, and product delivery mandate the proper systems engineering of any project. The concepts are folded into the capstone design experience at Cal Poly Pomona as listed in Table 1. The milestones of the case study are shown in Table 1, which mimics project management milestones encountered in private industry.

As seen in Table 1, the primary milestones of the capstone project were i) kick-off meeting with HILTI ii) site visit of students to HILTI facility iii) requirements document generation by HILTI to the Cal Poly ME 325 class, iv) weekly meetings with Cal Poly Pomona ME 325 student teams and course instructor, v) preliminary design review with customer representative and course

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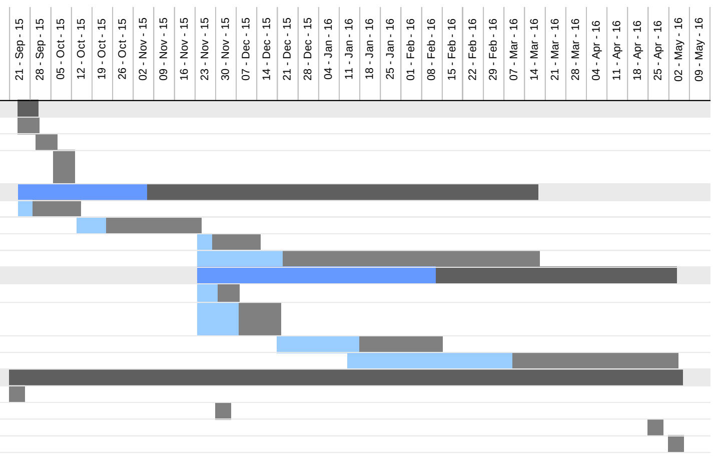
instructor, vi) customer design review with HILTI sponsoring mentor engineers, course instructor and invited panel of subject matter experts (i.e. other faculty and industrial advocates).

Table 1 – Typical Project Schedule and Milestones

WBS	Tasks	Task Lead	Start	End	Duration (Days)	% Complete	Working Days	Days Complete	Days Remaining
1	**Task Category 1**	[Name]	9/24/15	9/30/15	7	0%	5	0	7
1.1	FORM TEAMS		9/24/15	9/30/15	7	0%	5	0	7
1.2	SELECT MANAGER		9/30/15	10/6/15	7	0%	5	0	7
1.2.1	ASSIGN TASK LEADS		10/6/15	10/12/15	7	0%	5	0	7
2	**Task Category 2**	[Name]	9/24/15	3/18/16	177	25%	127	44	133
2.1	DEFINE PROJECT		9/24/15	10/14/15	21	25%	15	5	16
2.2	BRAINSTORM		10/14/15	11/24/15	42	25%	30	10	32
2.3	RE-ITERATION		11/24/15	12/14/15	21	25%	15	5	16
2.4	PROCUREMENT		11/24/15	3/18/16	116	25%	84	29	87
3	**Task Category 3**	[Name]	11/24/15	5/4/16	163	50%	117	81	82
3.1	DESIGN SELECTION		11/24/15	12/7/15	14	50%	10	7	7
3.2	DETAILED ENGINEERING		11/24/15	12/21/15	28	50%	20	14	14
3.3	CALCULATIONS		12/21/15	2/14/16	56	50%	40	28	28
3.4	BUILD AND TEST		1/14/16	5/4/16	112	50%	80	56	56
4	**Task Category 4**	[Name]	9/21/15	5/6/16	229	0%	165	0	229
4.1	KICK-OFF MEETING		9/21/15	9/25/15	5	0%	5	0	5
4.2	PDR		11/30/15	12/4/15	5	0%	5	0	5
4.3	CDR		4/25/16	4/29/16	5	0%	5	0	5
4.4	WHITE PAPER		5/2/16	5/6/16	5	0%	5	0	5



Many of these milestones and deliverables listed in Table 1 are in accordance with other capstone courses including Morgan *et al.*[6] and Slivovsky and Slivovksky[9] where desired outcomes from the independent learning and both oral and written communication in the capstone include increased technical competence, increased technical communication skills, and an understanding of the importance of lifelong learning. These encompass the so-called "soft skills" which often times evade proper assessment. Surveys administered to students in the first offering are largely in line with expected outcomes. An unexpected outcome, as the knowledge teams were initially formulated to increase technical competence, was that students reported an increase in the ability to work on teams. The assessment of the students' learning is discussed later in this paper under the assessment section.

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Figure 2 “Students from the Machine Design course visit HILTI’s Southern California Location.

Figure 3 is an image of the actual design problem to be addressed by the student teams. The technical challenge presented as a stifler required the students to use creativity coupled with their engineering analysis (stress analysis, mechanism design skills) in order to address a “think-outside-the-box” systems engineering approach to realize a problem solution for the customer. Figure 4, Figure 5 and Figure 6 are typical design solutions as proposed by the student teams.

Figure 3 “Example of Real-World Cold Press Requiring a New Solution”

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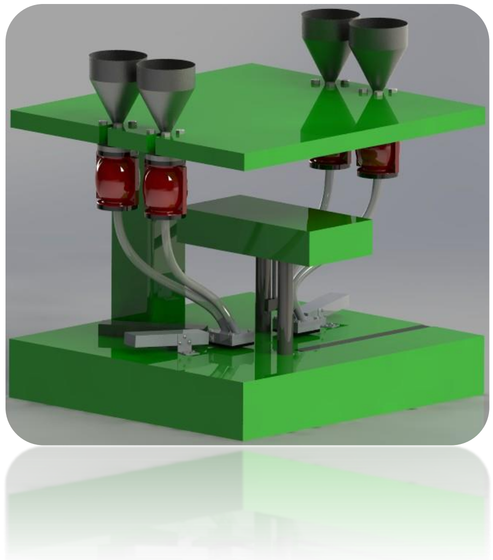

Figure 4 "Typical Result of Student Team for Realization of the Industry Sponsor's Solution"

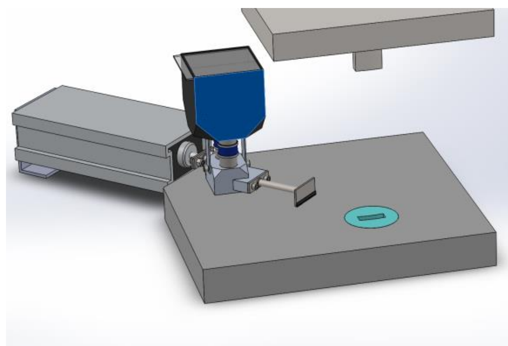

Figure 5 "Typical Result of Student Team for Realization of the Industry Sponsor's Solution"

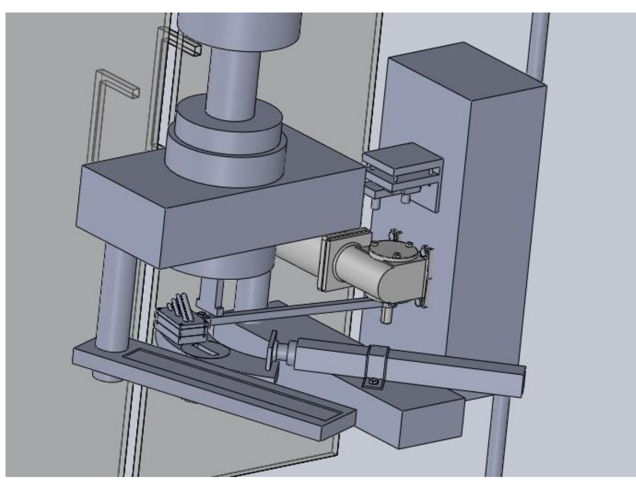

Figure 6 "Typical Result of Student Team for Realization of the Industry Sponsor's Solution"

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The HILTI company engineers acted as mentors, who came up with a "sitfler" problem whereby the teams of undergraduate students were required to develop an engineering solution. The students worked closely with the industry mentors and utilized their knowledge of machine design, mechanism design, dynamics, materials, economics, engineering graphics, etc. to realize a cost effective engineering solution base on customer requirement. The particular problem used by HILTI was the re-design of a Cold Press Tool and Die Mechanism. The project involved the feeding of a metallic powder at a certain rate. Figure 2 shows the a group of student in the ME 325 Machine Design course on-site at the field trip brain-storming the problem with the HILTI sponsoring mentor engineer, Mr. Matti Pajari.

A total of six teams were supervised during the course of a 10 week quarter. At the end of the quarter the HILTI team of engineering mentors visited Cal Poly Pomona to attend the CDR. The HILTI team then voted on the best design of the six teams. This assessment was used in conjunction with the grading rubric shown in Table 2.

Table 2 – ME 325 Machine Design Course Grading Rubric

Item	Grading
Weekly Theory Based Quizzes	15%
Theory Based Final Exam	15%
PDR Speech	20%
Weekly Meetings	10%
Scheduling	10%
Final CDR Speech	15%
Final CDR Report	15%

Assessment of Student Learning

Several previous researchers have focused on the assessment of capstone engineering projects. In the work of Davis *et al.*[20] details of a workshop is based on assessments developed under a National Science Foundation grant to create versatile assessments for capstone engineering design courses including development of scoring rubrics are presented. In the paper of Dartt *et al.*[21], collaborative work between engineers of multi-disciplinary nature is assesses and a case study of student initiated capstone engineering project is presented. Additionally, ABET assessment of the project is given in Dartt *et al.*[21]. In the study of Faust *et al.*[22], the students are required to take part in a year-long capstone program consisting of a one quarter lecture course and a follow-on two-quarter industry-sponsored capstone project. Feedback from students, alumni and capstone sponsors indicated that: a) students needed better preparation before starting their projects, b) we should introduce a realistic mini-project, and c) students should learn and apply project management, time management, teamwork, and communication skills. The redesigned lecture course of Faust et al.[19] has a term-long practicum project that mimics the follow-on project, requiring completion of a project from concept to test. Here we outline the assessment tools used to quantify the experiential learning of the students engaged on the

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industry sponsored capstone projects discussed previously. Weekly minutes were documented each week by a different group member taking meeting minutes. The Preliminary Design Review (PDR) is prepared by all team members and delivered to the customer in Powerpoint format. The Critical Design Review (CDR) is prepared by all team members and delivered to the customer in Powerpoint format. The schedule is given importance and its adherence is monitored. A contingency (back-up) plan of the design solution is also requested. The final report is a white-paper Microsoft Word document which is delivered to the customer at the conclusion of the CDR. The PDR and CDR metrics used here are akin to the study of Morgan *et al.*[6].
The use of Accreditation Board for Engineering and Technology, Inc. ABET[23] is proliferate in the assessment of undergraduate design curricula. ABET is the recognized U.S. accreditor of college and university programs in applied science, computing, engineering, and technology. ABET also provides leadership internationally through workshops, consultancies, memoranda of understanding, and mutual recognition agreements. Accreditation provides an opportunity for academic institutions to demonstrate they are committed to maintaining their programs' quality and that their programs are performing at the level required by the professions they serve. Programs undergo periodic accreditation to ensure that they continue to meet quality standards set by the profession. The result provides lasting benefits to students, the institution, employers, the professions, and society as a whole. The projects discussed herein are seen to fulfill the ABET a-k requirements. The general requirements for ABET (a-k) criteria are as follows:

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(d) an ability to function on multidisciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering
practice.

The majority of these ABET requirements have been fulfilled by the case study presented herein. This case study incorporates all aspects on an engineering endeavor, stressing the importance of communication. Soft skills and program management such as teamwork, presentation skills, writing skills, and ability to deal with ambiguity are emphasized throughout the capstone projects presented in this paper. The objective of the two-quarter capstone project experience outlined herein is to better prepare the students for the real-world challenges they will face after graduation, thus preparing them for life-long learning. Our objectives are in line with other studies such as Conn and Sharpe[2], Paretti and Burgoyne[3], Mirzamoghadam and Harding[5] and

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Morgn *et al.*[6].The Cal Poly Pomona Mechanical Engineering department curriculum objectives and outcomes which are derived from the ABET a-k are summarized below.

The Mechanical Engineering curriculum at Cal Poly Pomona objectives are designed to:

1. provide a solid background in mathematics and science coupled with an applications-oriented polytechnic approach in the presentation of engineering course material which may be synthesized over the first few years of one's engineering career
2. provide a comprehensive program of general education courses that will provide students with the necessary background to understand the economic, environmental, ethical, political, societal and cultural impact of their engineering solutions and decisions which may be implemented in ethical and professional situations soon after graduation
3. develop good written and verbal communication skills which will be used as a cornerstone in the early development years of a young engineer's career
4. encourage lifelong learning in their chosen field underscoring the importance to continue to obtain professional development and training on the job as needed during one's entire career
5. provide the necessary tools and background to become a professional engineer who will continue to be effective in the first few years of his/her professional assignment

Table 3 and Table 4 illustrate how the ME 325 course grading rubrics address the ABET a-k criteria, and the course learning objectives, respectively.

Table 3 - Course Grading Rubrics as Related to ABET a-k Criteria

	ABET a) – k) Item Addressed										
Course Grading Rubric Item	A	b	c	d	e	f	g	h	i	j	k
Theory Quizzes	X				X						
Theory Final	X	X			X						
PDR Speech			X	X		X		X	X		
Weekly Meetings			X	X							
Scheduling			X	X							
CDR Speech			X	X				X			
CDR Report			X	X	X	X		X	X		X

Table 4 - Course Grading Rubrics as Related to Mechanical Engineering Teaching Objectives

	Mech. Engr. Department Learning Objective				
Course Grading Rubric Item	1	2	3	4	5
Theory Quizzes	X	X			
Theory Final	X	X			
PDR Speech					X
Weekly Meetings		XX		X	

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Scheduling			X		
CDR Speech	X		X	X	X
CDR Report	X		X	X	X

The particular assessment tools used in the present case study were i) feedback on PDR and CDR by the audience, ii) review of the technical white paper report, iii) evaluation of team interaction skills by reviewing weekly progress of team members, iv) theory based quizzes and final examination. These tools also served to offer insight into soft-skill development, as the progress of the teams' communication skills was tracked from the beginning to the end of the project. For example of details of the assessment tools and the results consider the speech grading rubric shown in Table 5. The rubric of Table 5 was handed out to each student in the class and the industrial mentoring team. Each person evaluate each team, the scores where then tallied by the instructor and the grade for the speech was awarded to the team. At the end of the quarter the industrial team sat down with the instructor and ranked the designs from best to worst. The top three teams were informed of their 1st, 2nd and 3rd place rankings in order to provide feedback regarding their work.

Table 5 - Speech Grading Assessment Rubric

ME 325 Speech Grading Rubric	
Outline	
Background	
Body of Presentation	
Clarity of Graphs and Figures	
Accuracy of Calculations	
Professionalism	
Answers to Q&A	
Public Speaking	
Misc.	
Total out of a possible of 80 pts.	

Score: 10 = very good, 7.5 = good, 5 = acceptable, 2.5 = below average, 0 = unacceptable

Conclusion

This paper has presented the use sponsored capstone engineering projects for use in education of engineering students at the senior level. The use of engineering capstone projects for undergraduate engineering education. Assessment methods of student's soft skills and merits to the university have been presented. The example case study of sponsored undergraduate capstone design projects presented herein are seen to fulfill the above outcomes and objectives of the Mechanical Engineering program at Cal Poly Pomona. Once again, we reiterate that soft skills are emphasized throughout the capstone projects presented in this paper.

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Using Mock Bid Simulations to Enhance Construction Engineering and Management Education

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Abstract

In the engineering and construction industry, many companies rely on competitive bidding to obtain work. Students can read about how a general contractor assembles a competitive bid and they can listen to an instructor relay this information, but they do not understand how hectic and demanding the process can be. Students need to understand the importance of analyzing a subcontractor quotation quickly and accurately and the difficulties encountered when compiling a final bid price under the pressure of a time constraint. Learning objectives for most construction estimating course include educating students on the common practices of quantity take off and surveys, material costing, evaluation of specialty and subcontractor quotations, overhead pricing and the compilation of a final cost estimate. However, most students do not understand the difficulty that a construction engineers undertake assembling competitive bid proposals on bid day. This paper will present a class exercise that can be used to simulate the competitive bid day environment.

Introduction

The instructional objectives of the competitive bid exercise are for the students to evaluate subcontractor bids and select the responsible low bid in each category, and for the group to calculate a final competitive bid price within the allotted time frame. These instructional objectives allow the student to understand and appreciate the complexity faced by a contractor in assembling a successful competitive bid. The Mock Bid exercise is designed to provide students with a realistic experience of bid day conditions using a real project that they are likely to work on upon graduation.

Background

Beginning in the autumn quarter of 2008, the Construction Management Department at California Polytechnic State University, San Luis Obispo (Cal Poly) launched an integrated project based construction management curriculum. The basis behind the integrated curriculum was to create a series of practice courses, similar to an architecture studio model; however, each course would focus on a specific sector of the construction industry - Heavy Civil, Residential, Commercial, and Specialty Construction[8]. The concept behind the seminars was to integrate project controls, construction estimating and construction contracts and law into each of these courses and combine them with the construction methods topics pertinent to each industry sector. The integrated curriculum that the Cal Poly construction management faculty settled on led to the development of seven (7) project-based courses.

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They are as follows:

- Fundamentals of Construction Management
- Residential Construction Management
- Commercial Building Construction Management
- Heavy Civil Construction Management
- Specialty Contracting Construction Management
- Jobsite Construction Management
- Integrated Services Construction Management

Each of the project-based courses was based on a model of six (6) quarter-hours of laboratory credit total of sixteen (16) scheduled contact hours per week and an additional two (2) hours per week to be arranged for by the instructor. Based on a ten (10) week quarter system, students would receive a total of one-hundred eighty (180) hours of instruction[10]. Similar to courses offered through an architecture program, their concept was teach each course in a dedicated space equipped with models, samples, contracts, marketing documents, specifications, estimating guides, computer references, and other tools appropriate to that construction industry sector. In addition, the laboratory would be furnished with work stations for twenty-six (26) students who would have twenty-four (24) hour/seven (7) days of week access to the space[1].

The concept for the commercial building construction management course was to focus on the work performed by a commercial building contractor who may self-perform various work items required for the construction of a commercial building and who procures contracts for and manages the work of subcontractors who fabricate and install the remainder of the work items[3]. Typical work items include structural insulated panel system, structural steel, light-gauge steel construction, concrete formwork and reinforcement, site-cast and precast concrete framing systems, foundation and basements, masonry (concrete masonry units, natural stone, and glass masonry units), exterior wall cladding, windows and doors, roofing, and wall and floor coverings[4]. As one can imagine, the work of a commercial building contractor involves coordinating the multiple trades, to fabricate and install the work items mentioned above. Therefore, learning objectives focus on students understanding the construction methods for numerous work items.

In addition to the learning objectives related to construction methods for the work items mentioned above, students are provided an educational background on topics related to the building delivery process, governmental constraints on construction, loads on buildings, load resistance, structural properties of materials, thermal properties of materials, air leakage and water vapor control, fire-related properties, acoustical properties of materials, principles of joints and sealants, and principles of sustainable construction.

New Facility creates Opportunity for Experiential Learning

Since 1990, the Construction Management Department at Cal Poly had been soliciting donations for the construction of the Construction Innovations Center (CIC) on the Cal Poly campus. As part of the fundraising effort for the new $33 million, 30,000 square foot building which includes seven (7) dedicated labs, twelve (12) classrooms and lecture halls, and faculty offices, which was dedicated in October 2008, it was the goal of the College of Architecture and Environmental

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Design (CAED) to create an interdisciplinary learning laboratory for the CAED where students across the college would be able to design, build, and test a variety of building components. The result was a privately funded laboratory 5,000-square-foot lab named the Simpson Strong-Tie (SST) Materials Demonstration Lab for the donors to the laboratory which was dedicated in October 2010.

The integrated curriculum model described by Hauck and Jackson provides tremendous opportunities to engage teaching strategies far beyond the common lecture approach typically utilized in many single subject courses[3]. They proposed that various methodologies, such as cooperative learning, could be utilized in an integrated learning lab environment. Furthermore, they proposed a teaching approach for construction management education which requires students to be active participants in their own education. Students learn far more by doing something active rather than by simply watching and listening[2]. Therefore, to take advantage of the studio-laboratory format of the course proposed in the new curriculum, the faculty was challenged with developing experiential learning experiences to enhance student learning.

Experiential Learning

Experiential learning is learning through reflection on doing, which is often contrasted with didactic learning. Experiential learning is related to, but not synonymous with, experiential education, action learning, adventure learning, free choice learning, cooperative learning, and service learning. While there are relationships and connections between all these theories of education, there are also separate terms with separate meanings[3].

Experiential learning focuses on the learning process for the individual (unlike experiential education, which focuses on the transactive process between teacher and learner). An example of experiential learning is going to the zoo and learning through observation and interaction with the zoo environment, as opposed to reading about animals from a book. Thus, one makes discoveries and experiments with knowledge firsthand, instead of hearing or reading about others' experiences.

Experiential learning requires no teacher and relates solely to the meaning-making process of the individual's direct experience[7]. However, though the gaining of knowledge is an inherent process that occurs naturally, for a genuine learning experience to occur, certain elements must exist. According to David A. Kolb, an American educational theorist, knowledge is continuously gained through both personal and environmental experiences. He states that in order to gain genuine knowledge from an experience, certain abilities are required[9]:

- the learner must be willing to be actively involved in the experience;
- the learner must be able to reflect on the experience;
- the learner must possess and use analytical skills to conceptualize the experience; and
- the learner must possess decision making and problem solving skills in order to use the new ideas gained from the experience.

Course Approach, Learning Objectives, and Delivery Method

The commercial construction management course described above was designed to introduce

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students to the construction methods for various work items common to commercial building construction. Therefore the course was developed and delivered with the following goals:

- Understanding the types of materials used in commercial buildings
- Understanding how to read commercial building project plans and specifications
- Knowing the different types of equipment and materials used in commercial building projects
- Comprehend the design intent and constructability issues in commercial building projects
- Synthesizing the knowledge gained through class readings and exercises by participating in a construction site visit

The class was divided into several key methods of delivering course content: lectures, lab exercises, construction site visits, plan reading and material take-offs, and the use of interactive learning stations. Introductory lectures were given on each subject matter. Following the introductory lecture and an assigned reading, an in-class lab exercise was given for students to work on. Lab assignments varied by subject matter but primarily included construction document reading, preparation of cost proposals, and estimating and scheduling exercises.

The plan reading and material take-off exercises required the students to work within their four (4) person teams and review a set of commercial building drawings and specifications for an instructor-selected building located on campus. In addition, several construction projects were visited during the course, including commercial and institutional sites, varying between 30% and 90% construction completion. Following each site tour, students were required to submit a field trip report focusing on a particular aspect of the commercial building. Finally, throughout the class, a common experiential learning exercise was developed which allowed students to perform "hands-on" framing exercises using light-gauge steel. The following section discusses the design and implementation of the experiential learning exercise, including the learning objectives and outcomes assessments.

The Mock Bid Exercise

The mock bid exercise was based on the competitive bid process for an actual project. The project chosen for the exercise incorporates the need for the groups to evaluate subcontractor bids that they receive during the exercise. This exercise was set up so the students the entire term on the project culminating with a final submission at the end of the quarter/semester in the course. Throughout the course, the students are educated on how to perform a quantity take off, estimate the cost of work items, and how to evaluate subcontractor proposals. Additionally, they taught how calculate and assemble a final bid estimate for their proposal.

For large competitive bids, many contractors will assign the analysis of specific divisions of work to bid team members. Therefore, for the exercise, it recommended that each group divide up the work items within their group and each team member are then responsible for that section of the proposal, with the other group members responsible for cross checking each other's. For example, one person may be assigned the task of evaluating the Division 16 Electrical bids. Each team consists of a maximum of four (4) participants. The student teams are tasked with analyzing the following divisions of work: electrical, mechanical, finishes, specialties, and thermal and moisture protection.

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At the beginning of the mock bid exercise, the groups are told that they will be required to complete the exercise and submit their final bid with a listing of subcontractors to the instructor on a specified date and time. They are told that, as in industry, late bids will not be accepted. Each bid group is given the following documents at the beginning of the exercise:

- General instruction on how the bid exercise is to be completed. Guidelines for the bond amounts and general overhead and profit that should be applied to the bid.
- A bid form to submit final bid and subcontractor listing.
- A bid recapitulation sheet that is complete with the exception of the final bid amounts for the divisions of work that they are responsible to analyze, self-performed estimate amounts (provided with general instructions), bond costs and general overhead and profit.
- Subcontractor bids for the five divisions of work to be analyzed and a spreadsheet to aid in the bid analysis for each division of work. Each student is given approximately thirteen (13) bids to analyze during the exercise. This number of bids corresponds to the instructor's ability to evaluate the same number of bids in approximately one-third of the time that the students are given for the exercise. This may be a large number of bids, but the students need to experience the pressure of analyzing a large number of bids in a short time to simulate the competitive bid.
- A spreadsheet to aid in the bid analysis for each division of work. The following is an example of the spreadsheet for Division 15 bid analysis:

Organizing the Exercise

Listed below are the instructions given to the student teams for their in-class assignment. Each group has an assigned lead estimator. This person is in charge of assembling the final bid price. The bid has been broken down into the following areas for other individuals to evaluate:

- Division 01 — General Requirements
- Division 02 — Site Construction
- Division 03 — Concrete
- Division 04 — Masonry
- Division 05 — Metals
- Division 06 — Wood and Plastics
- Division 07 — Thermal and Moisture Protection
- Division 08 — Doors and Windows
- Division 09 — Finishes
- Division 10 — Specialties
- Division 11 — Equipment
- Division 12 — Furnishings
- Division 13 — Special Construction
- Division 14 — Conveying Systems
- Division 15 — Mechanical
- Division 16 — Electrical

Each group must decide the percentage of mark-up to add to their bid. The following are the guidelines provided to the student groups to use in their assessment of the appropriate mark-up:

1. The company’s office overhead is approximately 2.5% of the project volume in dollars.

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2. The company really needs the work right now, but there are three other bidding opportunities that look promising in the next three weeks.
3. The project duration is 24 months, and their firm likes to bring in approximately $10,000/month revenue on the proposed project manager and superintendent.
4. The company usually puts a 5 – 7% total margin on all projects.

Throughout the term, the teams are provided with answers to questions on their bids. Typical responses to questions that are fielded throughout the term include:

1. Bid price is for the base bid only; Student groups are not considering the pricing of the alternates unless specifically stated.
2. The evaluation of separate divisions should have a bid amount
3. A performance and payment bond is required for this project.

The first step in the Mock Bid is to prepare cost estimates for general conditions. Students then need to note that the quantity take offs and installation costs for other self-performed work that has been completed. These costs and take off quantities should then be entered into the Detail and Summary worksheets provided. Half way through the exercise, students receive bids for materials and subcontracted work. It is their responsibility for incorporating those costs into their bid and preparing a completed bid during this session. The bid opening then follows.

The student teams have been given the summary pricing sheets, some completed takeoff sheets, and the indirect job cost pricing sheet. For this exercise, they have to fill in the blanks on the estimate sheets, create a total, and distribute the indirect costs and end of bid items to each item and fill out the bid form, put it in the envelope, complete envelope, and turn it in on time.

Evaluating Student Learning

A "learn by doing" atmosphere where students are responsible for determining cost provides students an educational environment to experience tasks and the results of their decisions. In the construction industry, many employees are hired that do not have the training or coursework at the university level that provides them access to determine construction cost and produce cost estimates. New employees are often placed in a position, trained to do the daily tasks, but not enough time is available to provide them with the opportunity to experience the entire operation of the business. The mock bid exercise has many of the same decision and overview tools but in the commercial construction sector, a major area key to successful management is subcontractor management.

Conclusions

The students use the skills they have developed during the course of the class to meet the learning objectives of this exercise. All student groups are able to evaluate the subcontractor quotations, determine a final bid price, and turn in their bids by the designated time. This exercise enables the students to get a sense of the time constraints and difficult nature of the competitive bid. It also provides the students with an opportunity to pull all the pieces of information that were learned during the semester into a final concrete result. Students' comments regarding the exercise have been positive. Student groups commented that they felt pressure to complete the bid on time and had a better understanding of the pressures of compiling

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a competitive bid. Any time we can simulate an industry condition in the classroom, the students get a better sense of what they will encounter following graduation.

Recommendations for Future Implementations

Possible improvements to the exercise include giving the groups an opportunity prior to the bid exercise to decide "appropriate mark-up" and review scopes for their area of responsibility. In addition, if the bid exercise could be tied to a set of plans that the students have used in estimating assignments it could enhance their learning.

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Impact of a hybrid format on student performance and perceptions in an introductory computer programming course

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Abstract

This study describes the development and implementation of a hybrid format with a flipped classroom approach in an introductory computer programming course for mechanical engineers at California State Polytechnic University, Pomona (Cal Poly Pomona). Two sections of the course were taught during Spring Quarter 2014: One section utilized a traditional lecture-only format and met twice-a-week for 50 minutes, while the other section utilized a hybrid format with a flipped classroom approach and met once-a-week for 75 minutes. In the hybrid section, prior to each class meeting students were required to watch short video tutorials and complete pre-quizzes to prepare for the week's in-class activities. At the start of class, students were given a short graded quiz followed by a discussion of example problems. Most of the meeting time consisted of students participating in "Team Battles," an active learning exercise where groups of students would compete against each other to write computer programs as fast as possible. The hybrid section and the lecture-only section were granted access to the video tutorials and both sections performed similarly on quizzes and exams. Surveys given at the beginning and end of the course gauged students' opinions on the course material and format. Students in the hybrid section held a much more favorable opinion of hybrid courses by the end of the course compared to the lecture-only students and had a lower absence rate from in-class meetings. Feedback about the hybrid section was overwhelmingly positive and both sections felt the video tutorials helped them learn the material.

1. Introduction

During the past decade, numerous technologies have been developed that make it easier for instructors to extend their reach well beyond the classroom, allowing students to learn at a time and place most convenient for them. Now instructors can teach their courses with a hybrid format in which learning occurs both in class and online. These new technologies also enable instructors to "flip" their classrooms; by moving some content online, in-class time is freed-up to focus on the most troublesome concepts, discuss real-world applications of important topics, and increase the hands-on nature of the curriculum.[1]

There is growing consensus that the flipped classroom instructional model can have significant advantages over traditional lecture-only model. Bunce et al. (2010) demonstrated that students' attention frequently wavers during lecture and they often miss important concepts.[2] Flipped classrooms help solve this problem by allowing students to review lecture material online as many times as needed to fully understand a concept. Bunce et al. also found that students are able to focus longer when engaged in the active learning environment of a flipped classroom.

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Bishop and Verleger (2013) conducted a review of the literature on flipped classrooms and noted that "most studies conducted to date [only] explore student perceptions and use single-group study designs."[3] Similar findings were reported by Redekopp and Ragusa (2013).[4] This is especially true in engineering courses where the implementation of a flipped classroom model is uncommon. Those studies report that students' perceptions of flipped classroom materials and activities are usually favorable.

Some studies have examined the how a flipped classroom pedagogy affects academic performance in engineering courses. However, these studies often have one or more limitations. For example:

- Kaw and Garapati (2010) found that students in a traditional lecture-only section of a numerical methods course performed more poorly on exams compared to a section where students learned new material online using short video tutorials.[5] However, in-class time was dedicated to discussion only and the two sections were not taught in the same academic term.
- Thomas and Philpot (2012) examined students' final exam scores and course grades in a mechanics of materials course.[6] They found that there was no significant difference between traditional lecture-only sections and "inverted" (i.e., flipped) sections, but class attendance in the inverted sections was optional and primarily devoted to homework.
- Redekopp and Ragusa (2013) implemented many current best practices into a flipped computer architecture course including brief online assessments following video tutorials and in-class project work.[4] They found that there was no significant difference between the two groups of students on "lower order learning outcomes" but significant gains in "higher-order learning outcomes." However, like Kaw and Garapati, the traditional lecture-only section and flipped sections were not taught in the same academic term. Additionally, the video tutorials were relatively long (~30-40 minutes) – students generally prefer shorter videos which might have impacted their effectiveness.[7,8]

Despite the potential advantages of a flipped classroom pedagogy, most engineering courses still utilize the lecture-only instructional model in which class time is dedicated to instructors explaining concepts while students passively take notes. Before the flipped classroom model is adopted more widely in engineering courses, it is important to continue investigating the impact of this pedagogy on student academic performance and student perceptions in as many engineering courses as possible. This study examines the impact of a hybrid course with a flipped classroom approach on students in an introductory computer programming course for mechanical engineers, ME 232: Engineering Digital Computations, at Cal Poly Pomona. In developing the hybrid section, the author was part of a team that took elements of best practices in flipped classrooms from the studies discussed above, as well as best practices from studies in other scientific disciplines, and incorporated them into a single course. Specifically, the hybrid section had the following characteristics (studies demonstrating the use of a particular course element are referenced):

- Short (~5-15 minutes), modular online video tutorials[7,8]
- Online self-assessment following the video tutorials to make students aware of topics they do not understand well[9]
- Cooperative learning exercises in class instead of just working on homework[10]
- A mixture of questions on exams that test lower-order and higher-order learning outcomes[4]

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- A traditional lecture-only section and flipped classroom section were taught by the same instructor, the author, during the same academic term to reduce bias in grading and teaching styles[9]

One traditional lecture-only section of ME 232 and one hybrid section of ME 232 were taught by the author during Spring Quarter 2014. The current study examines the following question: How does a hybrid format with a flipped classroom approach, utilizing the course elements discussed above, impact student academic performance and student perceptions in an undergraduate engineering course compared to a lecture-only format?

2.1 Description of hybrid section

ME 232 is a 10-week introduction to computer programming course for mechanical engineers that teaches students about Microsoft Excel spreadsheets and how to write programs using Visual Basic for Applications (VBA). VBA is a language embedded in all Microsoft Office products, including Excel. In the hybrid section, the course is divided into weekly modules on Blackboard with each module investigating a different topic. All modules have the same structure to minimize confusion and students are encouraged to complete the following tasks in each module.

1) Introduction: Students watch a brief (~1 min) video of the instructor introducing the topic, then read the week's learning objectives. The videos are designed to prepare students for the current topic and to increase the instructor's online presence.
2) Learn new material: Students watch short video tutorials that discuss concepts related to the week's topic. Each video is typically ~5-10 min in length and the total amount of viewing time per week is ~30-60 min. The videos are hosted on the Cal Poly Pomona Mechanical Engineering Department's YouTube channel.[10]
3) Self-assessment: Students complete an ungraded "sanity-check quiz" to self-assess whether they understand the concepts discussed in the videos. Feedback is provided automatically if students provide incorrect answers. The sanity-check quizzes were created using Blackboard's Test feature.
4) Prepare for graded assessment: Students complete an ungraded "pre-quiz" which asks them to predict the output from a VBA program. The pre-quiz ensures that students understand the basic rules of programming before they apply them to real-world situations. Students download a PDF that contains the program from Blackboard and work on the problem offline. After obtaining a solution, students can check their answers using Excel.
5) In-class activities: Students and instructor meet once a week for 75 min in a computer lab. At the start of every class meeting, students take a graded quiz that is similar to the pre-quiz. The solution to the graded quiz is discussed immediately upon completion. Next, the instructor discusses examples and answers students' questions related to the week's topic. About half of the in-class time is dedicated to students participating in "Team Battles," an active learning exercise in which students are randomly paired in teams of three and presented with three short programming problems. Students are encouraged to help their teammates during the Team Battles and the four teams that complete the problems the quickest receive prizes that consist of a small amount of extra credit and candy.
6) Homework/Application: Students are given 2-3 homework problems for each topic. The homework requires students to apply the concepts learned during the week to solve

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engineering and everyday problems. The completed homework is collected through Blackboard every two weeks and graded by the instructor.

The creation of 42 videos tutorials that cover all concepts in ME 232 was the most time-consuming task in the development of the hybrid section. The videos were produced by the author on a PC using Camtasia Studio, a screen and voice capture software that allows the user to record in high-definition (HD) and has extensive editing capabilities. Most videos consisted of the author explaining programming theory using animated PowerPoint slides, then discussing an example of a VBA program in Excel. PowerPoint was preferred over free-hand drawing for its superior clarity of images and text, and because it allowed the author to focus solely on narration instead of drawing content. The author used a script for narration as it kept him on topic – reducing the length of the videos – and facilitated the creation of captions to enhance accessibility. The captions also may benefit students for whom English is a second language; over half of the students at Cal Poly Pomona are Hispanic or Asian/Pacific Islander.

Although the author narrates the video tutorials, the author's face and body are not shown on-screen so students can focus solely on the content. In order to increase the author's presence online, 10 additional videos were created that feature the author sitting behind a desk briefly introducing each week's topic. It was hoped that increasing the author's online presence would enhance the students' motivation to learn.[8] The videos were filmed and produced by a student assistant with experience in videography at a fraction of the cost of a professional videographer.

Students' grades were based on weekly quizzes (20%), bi-weekly homework assignments (10%), a midterm exam (25%), final exam (30%), group project (10%), and participation in online discussion boards (5%). The author monitored the discussion boards daily and would post a message at least once a week to stimulate discussion. Although students in the hybrid section did not receive credit for just participating in the Team Battles, they could obtain extra credit for completing the Team Battles quickly. Attendance in both sections was optional, but the weekly quizzes administered in the hybrid section gave those students a big incentive to attend each class session.

2.2 Description of lecture-only section

The lecture-only section met twice a week for 50 min in a computer lab. Class time was primarily used for lecture and students were encouraged to use computers to take notes and follow along with examples. Students in the lecture-only section we given access to the video tutorials and pre-quizzes, but were not given access to the sanity-check quizzes nor participated in Team Battles. Students' grades were based on the same criteria as the hybrid section (e.g., Midterm Exam is worth 25%, Final Exam is worth 30%, etc.). Table 1 summarizes the important differences between the two sections examined in this study.

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Table 1: Comparison of hybrid section and lecture-only section format

	Hybrid section	Lecture-only section
Weekly in-class meeting time	W 11:00am-12:15pm	M W 10:00-10:50am
Access to video tutorials	✓	✓
Access to sanity-check quizzes	✓	
Access to pre-quizzes	✓	✓
Participate in Team Battles	✓	
Number of quizzes [a]	7	4

[a] Both sections had four similar quizzes, as well as one similar Midterm Exam and one similar Final Exam.

2.3 Implementation of study

During Spring Quarter 2014, the lecture-only and hybrid sections met back-to-back on Wednesdays to reduce time-of-day bias, and the author taught both sections to reduce instructor bias. Six assessments – four quizzes, Midterm Exam, and Final Exam – were administered to both sections and contained similar content (see Table 2).

Table 2: Weekly schedule of quizzes and exams

	Week Number										
	1	2	3	4	5	6	7	8	9	10	11
Hybrid section		Q1	Q2	Q3	Q4	Q5	Mid	Q6		Q7	Final
Lecture-only section			Q1[a]		Q3		Mid	Q6		Q7	Final

[a] Quiz 1, Quiz 3, Quiz 6, Quiz 7, Midterm Exam, and Final Exam were administered to both sections and contained similar content. Due to scheduling issues, Quiz 1, Quiz 3, and the Final Exam were administered on separate days.

During the study, two surveys that were approved by the university's Institutional Review Board were deployed through Blackboard in both sections. The surveys were optional and students were not compensated for participating. A total of 20 students from the hybrid section and 25 students from the lecture-only section took at least one of the surveys.

A pre-course survey was deployed during the first week of class and obtained information on students' prior experience with computer programming and hybrid courses, as well as students' baseline opinions of their major, course content, and hybrid courses in general. 20 students from the hybrid section and 23 students from the lecture-only completed the pre-course survey. The post-course survey was deployed during the final week of class and measured changes in students' opinions, as well as obtained feedback about the course. Nine students from the hybrid section and 18 students from the lecture-only section completed the post-course survey.

3.1 Results – Comparison of prior academic performance and experience

Table 3 compares the two sections' academic performance, experience with hybrid courses, and experience with the subject matter prior to Spring Quarter 2014. A Student's t-test analysis indicates that the difference between the two sections' GPA and units completed prior to the course was not statistically significant at the 95% confidence level. Additionally, only three of the 45 students in the study had taken the course in the past; most students were taking the course for the first time. Both sections also had similar levels of experience with hybrid courses and

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computer programming. Therefore, it is unlikely that differences in the background of the two sections impacted the results greatly.

Table 3: Students' academic performance, experience with hybrid courses, and experience with computer programming prior to Spring Quarter 2014

	Hybrid section (n = 20)	Lecture-only section (n = 25)
GPA (mean ± 1σ)	3.39 ± 0.37	3.25 ± 0.49
Units completed (mean ± 1σ)	123 ± 53	108 ± 47
Students repeating course	1	2
	(n = 20)	(n = 23) [a]
Took at least one hybrid course	50.0%	52.2%
Knew at least one computer language	5.6%	8.7%
Unsuccessfully tried to learn a computer language	16.7%	17.4%
Never tried to learn a computer language	73.9%	77.8%

[a] Only 23 students in the lecture-only section took the pre-course survey

3.2 Results – Comparison of academic performance during the course

Both sections took four quizzes, a Midterm Exam, and a Final Exam that contained similar content. The first half of Table 4 lists the mean and 1σ scores for all six assessments and shows that both sections performed similarly on those common assessments.

Table 4: Student performance on common quizzes and exams

	Hybrid section (n = 20) Mean ± 1σ, %	Lecture-only section (n = 25) Mean ± 1σ, %
Quiz 1	85.7 ± 20.4	85.2 ± 24.0
Quiz 3	83.0 ± 29.4	87.2 ± 29.5
Quiz 6	78.2 ± 29.8	72.9 ± 35.9
Quiz 7	83.8 ± 30.7	69.9 ± 39.0
Midterm Exam	79.4 ± 14.2	80.1 ± 12.0
Final Exam	80.1 ± 12.1	81.9 ± 11.8
Midterm Exam sections		
Part 1: Short answer	60.0 ± 49.6	64.0 ± 47.4
Part 2: Predict output	81.7 ± 24.5	74.6 ± 31.7
Part 3: Write program	82.7 ± 24.0*	92.8 ± 14.9*
Final Exam sections		
Part 1: Short answer	87.0 ± 19.5	87.2 ± 13.1
Part 2: Predict output	88.8 ± 10.1	86.8 ± 32.2
Part 3: Write program	54.6 ± 29.2	64.1 ± 39.7

* A Student's t-test analysis shows there is a statistically significant difference between the two sections at the 95% confidence level. Only Part 3 of the Midterm Exam met this criteria.

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The Midterm Exam and Final Exam consisted of three parts: (1) In Part 1, students were given questions that asked them to recall a single programming concept and write a short answer response; (2) In Part 2, students were shown VBA programs that required the use of multiple programming concepts to predict the output; (3) In Part 3, students were given problem statements and had to write programs that would accomplish specific tasks. Questions from Parts 1 and 2 tested whether students were able to recall and comprehend VBA code, and thus tested lower-level cognitive skills. Questions from Part 3 required students to apply their programming knowledge to create programs and thus tested students' higher-level cognitive skills.[11] The second half of Table 4 compares the performance of both sections on all three parts of the Midterm and Final Exams. There is a statistically significant difference between the two sections only for Part 3 of the Midterm Exam in which the lecture-only section performed slightly better than the hybrid section. For all other parts, the difference between the two sections is not statistically significant.

Table 5 shows the student participation rate in online discussion boards and attendance rate for both sections. Although students in the hybrid section were required to use the class website to learn new content, the number of posts made during the quarter is similar to the lecture-only section. Both sections were required to post 10 times during the quarter as part of their grade, which likely influenced the number of posts. The absence rate was significantly lower in the hybrid section compared to the lecture-only section, possibly due to an assessment being given almost every meeting of the hybrid section but only occasionally for the lecture-only section.

Table 5: Participation rate on online discussion boards and class attendance during the course

	Hybrid section (n = 20) Mean ± 1σ	Lecture-only section (n = 25) Mean ± 1σ
Discussion board posts	6.45 ± 4.99	6.44 ± 4.65
Average absence rate (%) [a]	2.50 ± 2.67*	9.56 ± 4.56*

[a] Percentage of class that did not attend a typical class meeting

* A student's t-test analysis shows there is a statistically significant difference between the two sections at the 95% confidence level.

The sanity-check quizzes were intended to help students in the hybrid section self-assess whether they understood the content for a given week. Figure 1 compares the performance of hybrid section students on the Final Exam with the number of sanity-check quizzes attempted. There is no significant correlation between the two variables at the 95% confidence level, suggesting the sanity-check quizzes had no impact on student performance on the Final Exam.

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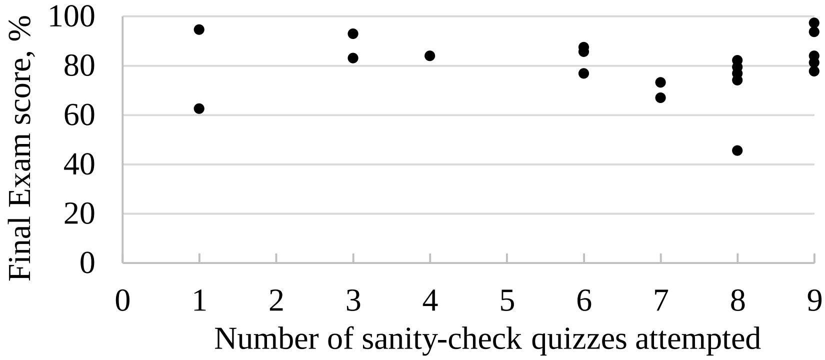

Figure 1: Comparison of Final Exam scores and the number of sanity-check quizzes attempted for students in the hybrid section. Each data point represents one student. There is no significant correlation between the two variables at the 95% confidence level.

3.3 Results – Comparison of survey results

Pre-course and post-course surveys were administered during Week 1 and Week 10 of the course, respectively. Common questions that used a five-point scale (1 = worst, 5 = best) on both surveys measured how students' opinions on a variety of topics changed during the course. Nine students in the hybrid section and 18 students in the lecture-only section took both surveys. Table 6 shows that both sections held a more favorable opinion toward computer programming by the end of the course. Interestingly, the hybrid section held a more favorable opinion of hybrid courses in general by the end of the course, but their satisfaction toward the major decreased somewhat. There was no significant change in the lecture-only section's opinion toward hybrid courses or their major.

Table 6: Comparison of pre-course and post-course surveys

	Hybrid section (n = 9) Mean ± 1σ		Lecture-only section (n = 18) Mean ± 1σ	
	pre	post	pre	post
Opinion of programming[a]	3.89 ± 1.05†	4.44 ± 0.53†	3.17 ± 0.86†	4.06 ± 0.94†
Opinion of hybrid courses[b]	3.56 ± 0.88†	4.56 ± 0.53†	3.11 ± 0.76	3.22 ± 1.00
Satisfaction with major[c]	4.67 ± 0.50*	4.00 ± 0.00*	4.61 ± 0.61	4.61 ± 0.50

† Wilcoxon signed rank test analysis indicates that the difference between the pre-course and post-course surveys is statistically significant at the 95% confidence level.

* There was insufficient data for a Wilcoxon signed rank test, so a paired Student's t-test analysis was used which indicates that the difference between the two surveys is statistically significant at the 95% confidence level.

[a] "I _______ computer programming." (5) really like, (4) somewhat like, (3) neither like nor dislike, (2) somewhat dislike, (1) really dislike

[b] "I _______ hybrid courses." Same five-point scale as in the previous question.

[c] "I am _______ with being a Mechanical Engineering major." (5) very satisfied, (4) somewhat satisfied, (3) neither satisfied nor dissatisfied, (2) somewhat dissatisfied, (1) very dissatisfied

Feedback about the hybrid course and flipped classroom format was generally positive. Table 7 shows that hybrid section students found the Team Battles effective, liked discussing the quizzes immediately after completing them, and felt the amount of in-class time per week was sufficient.

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Table 7: General feedback about the hybrid section from post-course survey

	Hybrid section (n = 9) Mean ± 1σ
Effectiveness of Team Battles [a]	4.11 ± 0.78
Opinion of quiz solutions being discussed in class [b]	4.67 ± 0.50
Opinion on amount of in-class time (75-min, once a week):	
• Sufficient to learn the material and should remain the same	66.7%
• Sufficient to learn the material but should be decreased	22.2%
• Insufficient to learn the material and should be increased	11.1%

[a] "The in-class Team Battles were _______ in helping me learn the material." (5) very effective, (4) somewhat effective, (3) neither effective nor ineffective, (2) somewhat ineffective, (1) very ineffective

[b] "I _______ that we discussed the solution to a quiz immediately after taking the quiz." (5) really like, (4) somewhat like, (3) neither like nor dislike, (2) somewhat dislike, (1) really dislike

In the post-course survey, students were asked for feedback about the video tutorials, course structure, and instructor. Students in the lecture-only section typically used the video tutorials for review when a concept was forgotten or when a concept was not clear from lecture.

- "I watch the videos whenever I do not remember/understand [something] from class."
- "If I missed some details from class, I would review by looking at the videos."
- "The video tutorials were generally used if I forgot a certain topic such as arrays, and to go through for review before exams and quizzes."

The hybrid section made many positive comments about the Team Battles and video tutorials.

- "I really enjoyed the team battles. I love how [they] forced me to engage in the material."
- "I loved how the course was constructed for [the] team battle. I'd enjoyed [the] team battle for having [a] little competition with classmates [and the] teamwork with the groups I [was part of]. Also, that made the learning very effective and fun. Everyday 75 minutes passed by so quick[ly], [as] if it was only like 5 minutes."
- "I really liked the [examples] in the tutorials. It was never confusing and each [example] simply demonstrated the concept without involving other concepts."

Although there were a couple of comments requesting additional examples in the video tutorials, the majority of the suggestions for improvement dealt with the amount of material covered in the course – too little or too much – and the weighting of assignment grades. No negative feedback was given for the hybrid course structure or the elements of the hybrid course.

4. Discussion and future work

Although it appears that the hybrid format made no significant impact on academic performance, surveys show that students in the hybrid section felt more positively about hybrid courses in general compared to the lecture-only section by the end of the course. This suggests that once a student experiences a hybrid course, he or she is more likely to be comfortable with the format in the future. The development of the hybrid course also produced additional benefits that are not quantifiable. The video tutorials were made available on the department's YouTube channel[10] and are now being used as a reference tool by other ME 232 instructors at Cal Poly Pomona. Numerous mechanical engineering students who took ME 232 with other instructors have

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informed the author privately that they found the videos helpful. The university's image has benefited as the videos have been watched tens of thousands of times by people all over the world. Additionally, the videos were repurposed to create Cal Poly Pomona's first MOOC, allowing the university to gain experience with that style of instruction. A paper about the MOOC will be presented at the ASEE National Conference in Seattle during June 2015.[12]

The results from Spring Quarter 2015 represent one data point in an on-going study. In future quarters, the amount of in-class meeting time and access to online resources will be adjusted to see if those factors impact student performance and perceptions about the material.

5. Acknowledgments

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Best Practices Guidelines for Successful Capstone Projects in Accelerated Technology Programs

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Abstract

A practicum or capstone project is an effective and useful end-of-program academic exercise that reinforces the ability of students to implement knowledge and skills they have learned in the program. Every academic program structures its capstone project with their own program specific objectives. An Information Technology Management accelerated program for nontraditional adult students utilizes a three-month duration capstone project, one of which is analyzed in this paper. Designing and implementing these types of projects enables hands-on practical real-world experience for students using an agile pedagogical and developmental approach. Agile development is a method for incremental software development where developers collaborate and make team decisions. These capstone projects are completed with minimal budget and within an intensive short duration of time. This paper starts with an academic analysis of the capstone project process and determines how it reinforces the academic objectives of this program specified by the Program Learning Outcomes. This study identifies criteria and determines ways to structure technical capstone projects to ensure development of valuable real-world learning experience by the student that is transferable to a workplace environment. Current acceptable methodologies for structuring capstone projects are evaluated and those which produce the best results in an accelerated format for the Information Technology Management curriculum are identified. The findings suggest that structuring and designing the capstone project using these guidelines is a practical way of improving student learning, meeting the required learning outcomes of the academic program, and completing a successful capstone project.

Keywords: Accelerated format, active learning, agile development, agile pedagogy, curricula, program learning outcomes, student learning.

Introduction

Information Technology Management (ITM) programs in most academic institutions integrate fundamentals in networking, wireless, database, client-server, information security, IT management techniques and tools, and hands-on experiences required to solve real-world industry problems[1]. The final capstone project, taken as the last two classes by the students before graduation, is a unique and valuable learning experience for students in many schools. It is usually designed to expand their outlook and create an opportunity for real world problem solving by means of integration of knowledge from multiple sources, multiple courses and

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multiple perspectives. Structuring these projects, especially in accelerated ITM programs, requires methodical planning and management in an agile process. At National University (NU) School of Engineering and Computing (SOEC) the Bachelor of Science in Information Technology Management (BS-ITM) degree is designed for professionals and IT managers to advance their abilities and proficiencies in this field and to apply learned skills in their work settings. This curriculum stresses multidisciplinary knowledge, presented to the students with a combination of theory, lectures, independent research, projects, and presentations, emphasizing and promoting self-directed learning. It also requires students to complete a capstone project in their final year, as a concluding experience, to determine the students' ability to apply program knowledge and skills to real-world problems[2]. These projects are defined, designed, implemented, tested, and presented to a group of experts for thorough review and assessment in a three-month period. This research demonstrates that structuring these capstone projects by following best practice guidelines is a repeatable, measurable and practical way to ensure a successful completion. Additionally, by using an agile approach, it improves students' learning experience and, simultaneously, meets all required learning outcomes of the academic program.

Literature suggests that a practicum or capstone provides a one-off end-of-program experience that fosters students' capacity to integrate their completed coursework and use the knowledge and skills they have learned[2,3]. Different academic programs structure capstone projects with their own specific objectives. Past work, available in the literature, mostly describes methods and practices for implementing successful capstone projects[4] including the benefits of promoting reflection and critical thinking[5]. Most of reported research focuses on the value of capstone projects to the students' learning and experience, but little work is available on the best practices guidelines for structuring and designing successful capstone projects, and the extent to which these methodical structures are a value-add to the sponsoring organizations[6]. This paper suggests some best practice guidelines and illustrates the findings with one capstone project for the BS-ITM program: Cox YMCA, with three students in the project group. It shows how the project, following the guidelines, fulfills the BS-ITM Program Learning Outcomes (PLOs), as established by the curriculum, and meets the accelerated schedule as required by the school. These findings demonstrate that structuring and designing the capstone project using the suggested guidelines leads to a successful and timely capstone project completion.

Capstone Project Objectives and Process[1]

The BS-ITM capstone project is a three-month two-course sequence in which students work on an original project that brings together concepts, principles and tools that are taught in the program. The deliverable is not a theoretical design but, rather, a working prototype of a real-world need that meets the requirements of an actively collaborating client. Students complete their projects and present their work to a panel of academic and industry professionals in this discipline. Grading is H (Honors), S (Satisfactory), or U (Unsatisfactory) only. Objectives of this course are to:

- Demonstrate the importance of Project Planning and Project Management
- Do in-depth research into the latest information technology developments

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- Complete a project plan for their business case
- Track progress
- Conduct the final group project presentation
- Complete the final group project documentation

Due to the accelerated schedule, it is necessary to use agile development techniques planning a well-delivered and optimized implementation. There is no room for wasted time or repeated steps. A team typically consists of three to four students who work with the instructor and supervisors who are faculty members. In most instances the instructor and the supervisor are the same. Also, as a project is defined there will be an end-user client who has agreed to sponsor the project and actively participate in the development life-cycle. At the end of the three-month duration, a working prototype is presented to a panel and the sponsor, and a formal report is delivered.

During these three months, the team meets with the instructor twice a week and with the end-user client as required in an agile development environment that consists of five phases:

1. ***Proposal:*** The team makes a short informal presentation of the needs of a prospective client and proposed project in the first week. Other students in the class and the instructor raise questions related to the program disciplines and the need to address all areas, consider, possible technical show-stoppers, and evaluate whether the project scope is deliverable in a three-month period. A project Proposal is the deliverable of this first phase.
2. ***Revision:*** With these suggestions and recommendations, the team refines the project, performs a detailed literature review and consults with the client to ensure a satisfactory solution. At the end of this stage, the team completes the project overview, literature review, a set of references used to this point, and a satisfactory summary of the project objectives and deliverables. The overview must clearly state the innovative ideas, features or implementations that are not already done or available in the literature. A project Overview is the deliverable of this second phase.
3. ***Functional Specification:*** In a typical project, the rest of the first month is used to finalize the project scope, schedule the remainder of the project life-cycle, perform any needed research, and initiate the design by completing a draft functional specification to meet the user's requirements. It is highly recommended that the first month also include prototyping high-risk areas, such as new platforms, technology, and tools that will be used in the project. A Functional Specification is the deliverable of this third phase.
4. ***Prototype Implementation:*** The second and the third month are used to implement a working prototype of the project, test, devise work-arounds, and ensure that all the features and requirements of the client and Functional Specification are met. Research on the topic continues and the reference list and citations are added. A demonstrable Prototype Implementation that meets the client's requirements is the deliverable of this phase.
5. ***Project Report:*** Finally, the report is created for submission and a project presentation is put together including a demonstration of the working product or prototype. The report is

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required to be in APA format consisting of an abstract, introduction, literature review, project feasibility, methodology, findings, conclusions, recommendations, references, and a user manual for the client. A Project Report is the deliverable of this phase. It is not unusual for these reports to lead to academic publications.

Best Practices Guidelines for Successful Capstone Projects

This section suggests some best practices guidelines for ensuring a successful completion of a capstone project on schedule. These suggestions support the premise that structuring, designing, and implementing a capstone project using the guidelines proposed in this research is a viable way of improving student learning, meeting the required learning outcomes of the academic program, and completing the capstone project on time. Structuring includes the five phases previously addressed, each with its own measurable deliverable. Suggestions for best practices guidelines are as follows:

A. ***Create a Sponsored Project:*** The capstone project should be an original project that brings together concepts, principles and tools that are taught in the program. It should involve program areas covered in the coursework to solve a real problem that they would encounter in their post academic employment environment. From this point of view, it is beneficial and recommended that the project is proposed by corporate sponsors, in most cases by current employers of the students or other corporations looking for getting a prototype or a project implemented in a three-month duration. Corporations and business units are invariably interested in this joint effort for their business reasons[7], as a source of inexpensive technical resource that enables them to complete a quick prototyping of a proof-of-concept or a project completion in timeframes where it might not be otherwise possible[5,7]. This also provides the organization with an opportunity to contribute to student learning, and, in many cases, recruit good employees. By working with the sponsor, students experience real-world opportunities, issues, and their priorities. Project requirements are real and usually involve multiple disciplines like engineering, technology, and business. This provides the students a valuable opportunity to understand that a project involves many actors (developer, administration, customer, etc.) and all converge together with their specific requirements.

B. ***Ensure the Project Meets all PLOs:*** It is imperative that the capstone project meets all the PLOs required by the program. The NU BS-ITM program is a professional curriculum based on modern Information Technologies (IT) and IT management techniques. It facilitates students to learn analysis, problem solving techniques, advanced IT design, and IT management. The mission of the program is reflected in the PLOs as follows[1]:

   1. Demonstrate an ability to set up and integrate local and remote server and workstation computers with proper user authentication to preserve user privacy and confidentiality.
   2. Demonstrate the ability to plan an integrated system that involves computer applications to satisfy specific business processes.
   3. Demonstrate, manage and administer a LAN and wireless networking environment.

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4. Design, develop, administer, and support a robust relational database management system.
5. Apply concepts of best practices in information technology management and security to enterprise processes.
6. Describe the ethical challenges that confront an IT professional
7. Demonstrate written and oral communication skills in collaborative environments by participating on teams that address solutions for IT management challenges.

In this BS-ITM program, students learn theory, principles, and hands-on activities in the discipline through twelve one-month duration courses. Designated PLOs are achieved at the conclusion of the capstone project that span three months, covering areas of networking, wireless, database, client-server, information security, IT management techniques, and tools. It is suggested that the definition phase of the project include a detailed breakdown analysis to ensure that all required areas are covered in the project.

C. ***Clarify Project Requirements and Assessment Criteria:*** All BS-ITM capstone projects are assessed by a Faculty Judging Panel consisting of faculty members and industry professionals. An “Assessment of Learning Outcomes” shown in Figure 3 is used, that contains all the assessment criteria and metrics. It is essential that this grading rubric is discussed with the team and the breakdown of each item clarified. Note that the evaluation form in Figure 3 has the old name of the school, School of Engineering, Technology and Media (SETM). This name was recently changed to School of Engineering and Computing (SOEC).

D. ***The Team Takes Ownership:*** The team must be excited and proud of their project. In many cases the instructor is astounded by a team's hesitancy to take charge. Even in the industry, a notion of personal accountability is one of the least understood characteristic of a productive work environment. The same applies to these teams during the capstone projects. The instructor, working with the team, must make sure that the students are invested in the project and engaged with the team goals. The experience of the authors with capstone projects always amazes them by what the students are capable of accomplishing on their own when they take ownership of the project decisions. In project meetings, encourage each student’s opinions on important decisions affecting the project. Give the students a voice so that everyone is convinced that they are able to contribute to the success of the team. Ensure that it is understood that it may not be possible to accept everyone’s opinion every time, but they must feel like they are being heard. This goes a long way toward creating trust, relationships, collaboration, and improved engagement in the project. In addition, students often hesitate in making decisions and in taking ownership of a project because they are not sure if they should. They feel like they need to be told what to do or they are afraid of making a decision with which others may not agree. It is suggested delegating effectively and communicating clearly where the decision-making must happen. Allowing the students to make those decisions goes a long way in ensuring the team takes ownership of the project leading to a successful and timely completion.

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E. ***The Team Critically Evaluates Project Feasibility:*** Feasibility analysis is a critical part of project definition. This step defines the scope, limitations, and features of the project. It is recommended that the team evaluate the following aspects of the project feasibility:

1. Operational Feasibility: Operational feasibility is a measure of how the proposed project solves the problems recognized or meets the opportunities identified. To ensure project success, desired operational outcomes must be analyzed during the early stages of the design phase. This is an essential part of project definition that needs to be completed up-front.
2. Technical Feasibility: The team must have a clear understanding of the available technical resources of the team and the areas that they are vulnerable. Their plans going forward must include training and learning the new items and areas. An example of this could be the lack of experience with the Android platform and the resources available to learn and use this technology. Available and required hardware/software to complete the project must be analyzed and understood.
3. Schedule Feasibility: Schedule feasibility is a reasonable measure of the project duration. BS-ITM capstone projects are scheduled on an aggressive time line. Projects will not be considered successful if not completed within the given timeframe. The team should be encouraged to estimate the time each part of the project will take to complete. Given the team's technical expertise, the team must ensure that the project deadlines are reasonable.

F. ***Detailed Literature Review to Identify New Areas of the Project:*** A literature review provides the foundation and the definition of the project. The step must be a planned and in-depth activity summarizing past work and research available in this field. The outcome must articulate the innovative ideas, features or implementations of the project that are not already done or available in the literature. Also, this step should describe how the new solution proposed by the project potentially fills the gaps in this area. It is important to organize this effort in a way that is relevant, streamlined, and coherent, including synthesis of prior work and results. This part of the report must include all references to prior works used.

G. ***Alpha-Prototype New Technology and High-Risk Items during the First Month:*** An alpha-prototype is an initial version of the project comprised of test modules that are created in an agile manner. This provides the team with an insight into the functionality of the design and changes needed to ensure a working, deliverable project for the client. This also enables the team to ensure the viability of the key and high-risk components of the project. Encourage early creation of this alpha-prototype to ensure that the project scope is achievable, viable, and meets the requirements.

H. ***Create a Detailed Schedule and Monitor Progress Weekly:*** The importance of a satisfactorily detailed schedule, using Microsoft Project for example, cannot be overemphasized. This forces the team to step through each part of the project and evaluate it with respect to definition, resources, practicality, and time. Responsibilities among team members are clarified and this leads to individual and team ownership. The realization of the fact that one team member missing the schedule impacts other parts of the project brings the whole team together.

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This schedule must be agreed to by all members of the team and followed closely. As is often the case there is always a possibility of running into unforeseen issues. The possibility of some slippage or rework, especially with new technologies or requirements, must be incorporated into the schedule. It is recommended that a Project Progress meeting be held on a weekly basis or more frequently as required, with mandatory attendance of all team members. It is recommended that the instructor and the mentor also attend as often as possible to guide the team as necessary.

Analysis and Validation Using an Illustrative Example[8]

This project, being used an example, consists of upgrades and modifications to the Cox Tech Center lab at the YMCA of San Diego County – Youth & Family Services Department (YFS). All recommended steps were followed as described in the previous section. The project involved the upgrade process from the existing legacy network infrastructure to a more robust network

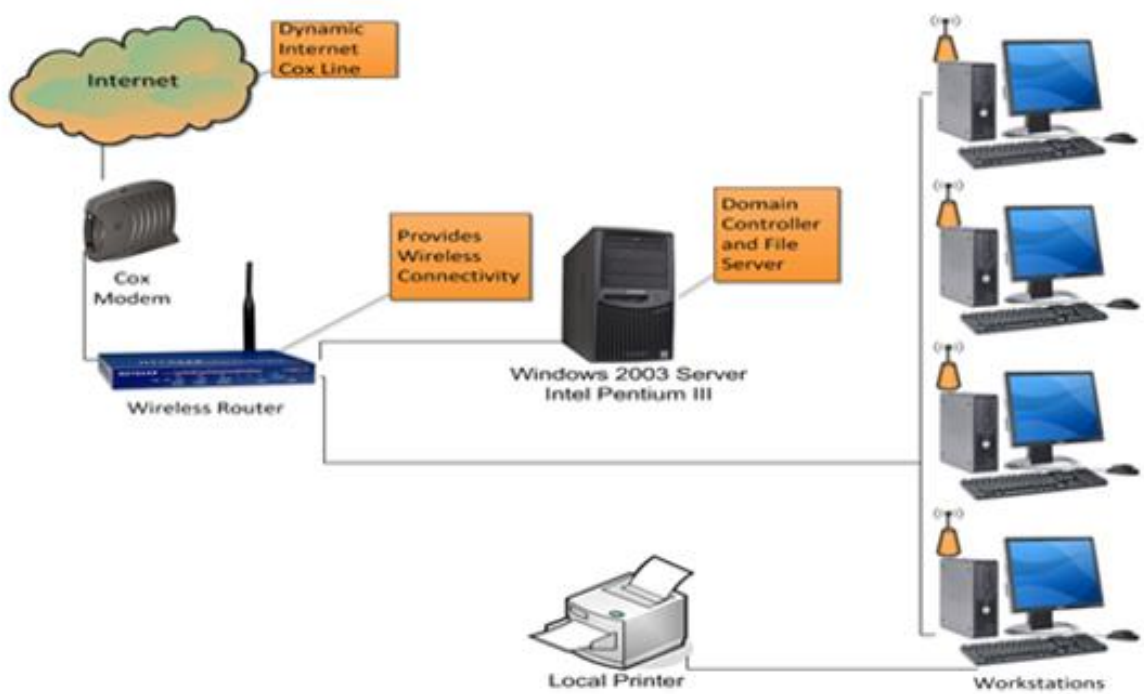

Figure 1: Pre-Upgrade Physical Description

solution that utilizes newer technologies. At the core of the upgraded network were two servers running Windows Server 2008 R2 configured to provide redundancy and various services to the Cox Tech Center and its users. Among the added functionality was the use of Microsoft's Hyper-V for virtualization along with the deployment and configuration of Microsoft System Center Essentials 2010 for centralized network management. The design and implementation began with an analysis of the pre-upgrade network infrastructure and an assessment of the services offered through the center. This process led to the understanding of their requirements and an effective solution achievable using available resources.

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Figure 1 shows the pre-upgrade physical description of the network as determined by the project team during the initial evaluation. Internet service was provided through a dynamic service communication line coming into the facility, which hindered remote connectivity options. The existing Netgear wireless access point, which offered many advanced features, was not being used to its full functional capacity. The server, being used as the Primary Domain Controller, was classified as a legacy device due to hardware specifications and configuration. Additionally, the system was running an outdated Window Server operating system. Figure 2 shows the design of the upgraded network, providing an overview of the core services offered by two servers, Server 1 and Server 2. Server 1 "Athena" was the hub of the network (Windows Server 2008 R-2). It was the Primary Domain Controller with Active Directory (Group Policy) using Dynamic Host Configuration Protocol (DHCP). Server 2 "Hyper-V" served as the Virtualization and System Management (Windows Server 2008 R-2) server with roles as the Redundancy and Secondary Domain Controller, the Hyper-V Virtualization, and the System Center Essentials 2010. This project design and implementation met all the client acceptance criteria.

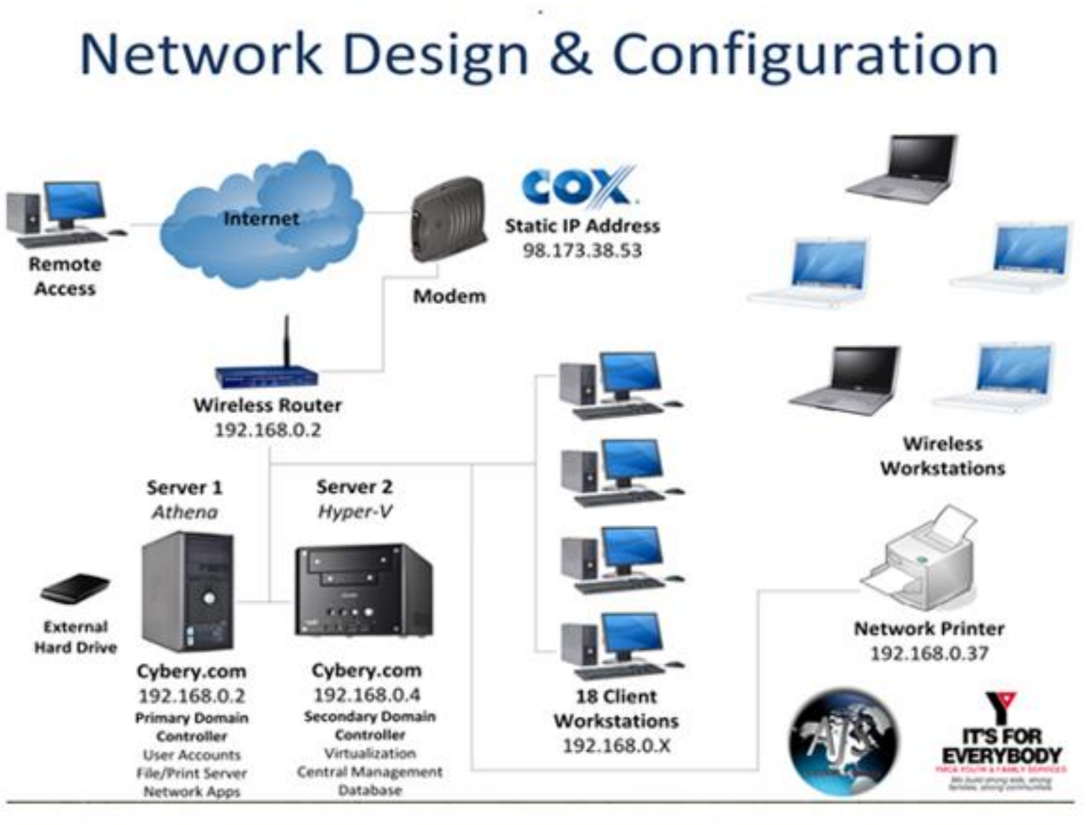

Figure 2: Post-Upgrade Physical Description

In this BS-ITM capstone project, a detailed and in-depth literature review was conducted by the students in order to identify the main user requirements, and identify a practical cost-effective solution that could be implemented in the limited three-month time period available. The Judging Panel, after reviewing the written capstone reports, participating interactively with the students

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during the project presentations, and scoring the projects using the assessment rubrics, submitted their individual evaluations to the BS-ITM Program Lead faculty. The summary of these evaluations for these projects are shown in the Figure 3. Each student in this project received the H (Honors) grade.

NATIONAL UNIVERSITY
School of Engineering, Technology and Media

Assessment of Learning Outcomes by Faculty Judging Panel
Academic Program: Bachelor of Science in Information Technology Management
Information Technology Project I and II [ITM490A and ITM490B]

PLO	Program Learning Outcomes	Assessment Criteria and Measurable Outcomes	TEAM GRADE [25 MAX] Example Project
1	Demonstrate an ability to set up and integrate local and remote server and workstation computers with proper user authentication to preserve user privacy and confidentiality.	Report	22
		Prototype Demonstration	22
		Presentation	23
2	Demonstrate the ability to plan an integrated system that involves computer applications to satisfy specific business processes.	Report	22
		Prototype Demonstration	23
		Presentation	20
3	Demonstrate, manage and administer a LAN and wireless networking environment.	Report	23
		Prototype Demonstration	22
		Presentation	24
4	Design, develop, administer, and support a robust relational database management system.	Report	23
		Prototype Demonstration	21
		Presentation	23
5	Apply concepts of best practices in information technology management and security to enterprise processes.	Report	21
		Prototype Demonstration	22
		Presentation	24
6	Describe the ethical challenges that confront an IT professional	Report	23
		Prototype Demonstration	20
		Presentation	24
7	Demonstrate written and oral communication skills in collaborative environments by participating on teams that address solutions for IT management challenges.	Report	23
		Prototype Demonstration	23
		Presentation	22

Figure 3: PLOs and Project Grading for the Example Project

Conclusions

Capstone projects were designed, implemented, and analyzed to support the premise that structuring and designing a capstone project using the approaches proposed in this research is a viable way of improving student learning, meeting the required learning outcomes of the academic program, and completing a successful capstone project. The specification of specific

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structure such as the five suggested phases – Proposal, Revision, Functional Specification, Prototype Implementation and Project Report – each with its deliverable simplifies the management life-cycle. The example project was created, developed, and tested by students under the supervision of faculty members. PLO requirements set by the program were met. The project was successfully presented to an audience comprised of representatives of the client sponsoring organization, program sponsors, industry experts, and university faculty. Based on the successful demonstrations of the project prototype, the students were assigned appropriately high grades. The project was also analyzed on the degree to which it met the PLOs. Students made a formal presentation to a Faculty Judging Panel that provided an evaluation based on an assessment rubric. Client sponsor, participating in this creative process was most enthusiastic in the delivered product. The Panel presented its conclusions to the program Lead Faculty who gave official grading of the capstone project and the project was approved for the degree requirement. This paper gives an academic analysis of the capstone project process, and determines how it reinforces the academic objectives of this program and individual Program Learning Outcomes (PLOs), as established by the program, and meets the accelerated schedule. These findings demonstrate that structuring and designing the capstone project using the suggested guidelines leads to a successful capstone project.

Recommendations for Future Research

Understanding the emerging role of the instructor and how the instructor can help and contribute to the capstone project process needs to continue. This may include evaluating available and emerging technologies for more efficient content creation and distribution that may speed up completing project deliverables on schedule. Virtualization and the use of Big Data are some of the technologies that have enormous potential in this emerging education paradigm.

The logistics of contacting and understanding the requirements from the community sponsoring organizations, that may be a capstone project prospect, needs to be improved and eventually automated. The authors are assessing the viability of building an online system where member organizations can log in and post their requirements for possible projects. These requirements will be analyzed to determine if the suggested project is feasible in this accelerated format, relevant to the program areas, includes academic relevance to the different areas covered in the program, and the organization has the resources required to work with our students to define and collaborate in this capstone project. With this application, students will more easily identify potential projects, analyze the needs with the clients, and request assignment to a specific project. These requests, in turn, can be reviewed by instructors, and the appropriate assignments can then be made.

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Student Chapter Development and Engagement in Engineering Majors: The NECA Student Chapter Case

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Abstract

Student chapters provide an opportunity for students to develop additional knowledge and skills to those acquired during their college life as well to work in multidisciplinary teams and participate in projects and competitions outside of their school's setting. Large professional and trade organizations have encouraged the creation of student chapters to promote their profession and interests and to have students experience how work is developed in their fields. Students are invited to interact with professionals in different settings and occasions that promote networking, learning about technical topics, and improving their presentation and interpersonal skills. The basis of student chapters' work is "tell me, and I will forget. Show me, and I may remember. Involve me, and I will understand". They basically help students to put into practice knowledge acquired in coursework and interactions with industry practitioners. Within this context, this paper discusses a research project funded by ELECTRI International about promoting careers in the electrical contracting business through student chapter engagement and research on energy efficient projects. The paper discusses the result of a survey about NECA student chapters across the nation, gives examples of activities developed by the students and how they relate to ABET outcomes, and suggests the main tasks to successfully start and manage a student chapter using San Diego State University NECA student chapter as an example. Results indicated that students value the networking opportunities promoted by student chapters, revealed that NECA student chapters enjoy good support from their local chapters and faculty advisors, and regularly promote activities such as general meetings with members and/or guest speakers, participate in student competitions, field visits, and networking events. Finally, the discussion about how to start and manage a student chapter, and how its activities relate to ABET outcomes, uses the NECA student chapter at San Diego State University to illustrate how students have been working on activities that have helped them earn course-related credits in regular and capstone courses, as well as how they improved their performance in competitions throughout the years.

Introduction

"Tell me, and I will forget. Show me, and I may remember. Involve me, and I will understand." This old saying summarizes the role of student chapters in supporting engineering education. The student chapters addressed in this paper are organizations based on institutions of higher education, which are committed to partnering with the industry organizations to provide students with real world experience and start them early on life-long learning and professional engagement. The work presented in this paper was developed as part of project funded by ELECTRI International about documenting activities that can be developed to successfully start and run student chapters. While the topic of establishing student chapters is not new, the author is not aware of comprehensive studies that discuss their role as part of the engineering education,

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and the mechanics of running student chapters. The paper aims to contribute to the literature on fully integrating extra-curricular activities, like the work developed by student chapters, in engineering education. The discussion starts with results of a survey in which students provided their feedback about the specific roles of National Electrical Contractors Association (NECA) student chapters. This survey was used to elicit items that students consider relevant when working in NECA student chapters, and whether they receive credits for the work they develop as part the Green Energy Challenge (a national competition sponsored by ELECTRI International). The paper ends with a discussion of how student chapters support accreditation outcomes for engineering programs and suggests activities to promote student engagement with student chapters. The activities developed by the NECA student chapter at San Diego State University are used as a baseline for the discussion.

Student chapters, industry support, and professional engagement

The Grand Challenges for Engineering defined by the National Academy of Engineering (NAE 2012)[1] include items such as make solar energy economical, restore and improve urban infrastructure, and advance personal learning. In this context, the work of NECA student chapters and their participation in the Green Energy Challenge (GEC)[2], the major competition these chapters are encouraged to participate in, provide students with an opportunity to address issues related to the three challenges identified above. Students form teams that work on a real world problem that usually involves retrofitting buildings to be energy efficient and creating micro grids, and finally proposing a full-fledged solution to get the project procured and built. The proposal includes the basis of design and the assumptions made to develop the project, identification and use of rebates, scheduling, estimating, and an outreach component.

The technical side of the GEC proposal exposes students to the problem at hand, and the challenges of gathering accurate data for the design, schedule, and estimates. Professionals working in the industry mentor the students towards defining the problem and identifying potential solutions, including but not limited to the choice of products and their sizing, financing, and the organization of labor to build the project. The problems tackled on the technical side of the GEC proposal directly address NAE's Grand Challenges related to solar energy, infrastructure, and personal learning as students seek solutions to the problems at hand. Meanwhile, as the technical side of the GEC proposal takes shape, students are encouraged to network with industry professionals in meetings promoted by NECA, participate in training sessions, and reach out to their campus and local community to develop the outreach portion of their projects. The outreach side of the proposal opens new doors to the students as they meet industry professionals and see how engineering activities take place in their community, and help the students get engaged with local organizations to promote energy efficiency awareness and market engineer careers to K-12 students.

The involvement of students with student chapters also contributes for a change in their perceptions about the engineering field and the engineering profession as observed by Litchfield and Javernick-Will (2013)[5]. Students exposed to hands-on activities developed by student chapters in real world settings realized that: they experienced how the engineering profession would help them balance multiple interests related to application of technical knowledge and helping communities; identified a niche that they wanted to work in, or even that they needed to

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readjust their expectations about the field. In other words, student chapters allow students to safely try different fields and activities and decide on their fields of specialization.

The literature on efforts to engage students with local professionals and expose students to field experience suggests that these efforts might work best when the activities are somehow part of the students' coursework and managed by student chapters alongside their program of origin. Opfer and Shields (2008)[3] describe an undergraduate professional seminar for construction students organized by a student chapter in the University of Nevada, Las Vegas (UNLV), in which students attend a series of presentations by industry practitioners. Even though students do not get credits for these seminars, which are offered throughout eight semesters while they are at UNLV, they are required to attend the seminars and get exposed to industry practices. The student chapter officers get to manage the seminar and help the program offer this opportunity to their students,

The close relationship between engineering programs and the industry, and its benefits, are also discussed by Soltani et al. (2013)[4]. Having a degree is no longer the main condition necessary for recent graduates to get a job. Recent graduates should be able to demonstrate that they have the skills necessary to develop work for potential employers, and have experience in executing the tasks on the workplace. Soltani et al.'s study revealed that engineering programs that are sponsored by industry partners displayed a closer match between the requirements of employers and the interests of students. In programs where industry partners sponsored internships, students had a chance to develop skills required to find jobs, academics developed closer links to the industry, and employers had a chance to develop and retain professionals in their businesses. It is worth mentioning that many of the NECA student chapters also benefit from internships provided by the local NECA chapter members sponsoring the students' activities. These internships allow some of the students to have their first internships in the industry and get exposed to the electrical contracting business.

In summary, activities developed by student chapters support the goals of engineering programs, strengthen the links between institutions of higher education and the industry, and promote a better match of interests of students, employers, and academics.

Development of Skills in Student Chapters

Activities developed by students in projects sponsored by student chapters help them build skills that are in line with those promoted by the Engineer of 2020 initiative by the NAE[6]. The skills promoted by the Engineer of 2020 initiative are organized in 4 majors pillars, as outlined by Rover et al. (2013)[7], include: leadership development, systems thinking, innovation, and global awareness and understanding. Table 1 summarizes a set of skills that can potentially be acquired by student chapter members as they engage in chapter-sponsored activities and how these skills relate to the Engineer of 2020 initiative.

Participating in competitions, interacting with practitioners, interning with local businesses, and conducting research are some of the most rewarding activities for students as they get ready to enter the job market. Not all students are involved with all chapter activities, but Table 1 gives an idea of what kids of skills can be developed as students participate in specific activities.

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Table 1: Activities developed by student chapters and potential resulting skills

	Activities usually developed by student chapters									
	Manage the chapter	Organize events	Participate in general meetings	Interact with practitioners	Engage in research	Participate in training sessions and field trips	Intern with local businesses	Participate in competitions	Engage in community service	Work with interdisciplinary teams
Engineer of 2020 skills										
Leadership development	X	X		X				X		X
Systems thinking				X	X		X	X	X	X
Innovation		X			X					X
Global awareness and understanding			X		X		X	X	X	X
Specific Skills										
Apply classroom knowledge					X		X	X	X	
Organize business proposals	X	X		X			X	X		
Network				X			X	X	X	
Develop technical skills				X	X	X	X	X	X	
Manage people and projects	X					X		X		
Learn about LEED certification			X	X	X	X		X		
Learn about how to finance green projects			X	X	X	X		X		
Research how existing projects operate				X	X	X		X		
Deliver presentations	X				X		X	X		

Feedback from members of NECA student chapters

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As part of the project funded by ELECTRI International on engaging students with student chapters, a survey was developed to obtain feedback on students' perceptions about chapter activities and what students are getting out of these activities. Results of the entire survey can be found in the report "Promoting Careers in the Electrical Contracting Business through Student Chapter Engagement and Research on Energy Efficient Projects" by the author (Alves 2014)[8]. The goal was to identify potential areas of improvement in the way NECA student chapters are run and managed by local NECA sponsor chapters and the national chapter.

The survey was mainly designed based on the author's experience in advising three student chapters at San Diego State University, namely: Associated General Contractors of America (AGC)/ Construction Management Association of America (CMAA), United States Green Building (USGBC), and NECA. The survey included multiple choice and open questions to characterize the membership and the activities developed, questions seeking the students' opinions using a 5-point Likert scale (e.g., not important at all, slightly important, important, fairly important, extremely important), and open questions to document suggestions. Before the survey was deployed to all NECA chapters in the United States, a pre-test was conducted and students at San Diego State University gave feedback to the author regarding the wording of questions and issues regarding the online tool used to deploy the survey to chapters across the nation. Changes were made accordingly to address the students' comments. The survey was then presented to an advisory board that assisted the author during the project, a new round of feedback was gathered, and once again changes were made to the survey. Finally, the survey was distributed nationally with the help of NECA National and 32 students answered the survey. A research protocol was submitted for the Institutional Review Board (IRB) review and approval at San Diego State University.

The survey was deployed using the online tool Surveymonkey.com and no identifiers were collected to protect the identity of the respondents. A copy of the complete survey can be found at the report by the author[8]. The survey had five basic sections as outlined below but only a few questions and results deemed more relevant for this paper are presented:

- Personal information – participants were not identified. Information about their background was collected to characterize the membership of NECA student chapters.
- Chapter information – activities developed by the student chapter and their frequency and participation in competitions were covered in this section.
- Green Energy Challenge (GEC) – preparation for and participation in the GEC was addressed in this section.
- Parent chapter support (sponsor chapter) – this section captured students' knowledge and impressions regarding support from the local chapter.
- School support – this section aimed to understand the support provided by different schools to the student chapters.

Limitations regarding this survey include the small number of respondents, and the fact that chapters with more active team members and advisors might have been more inclined to respond than other chapters. Additionally, several multiple choice questions had an option indicating "not sure", which was intentionally included to capture the fact that some students might not know about opportunities and resources offered to students who are part of the NECA student chapters.

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Finally, no statistical analysis was conducted, the results are reported based on the frequency of answers and the written feedback provided by respondents in open-ended questions.

Results and Analysis

The 32 students who answered the survey were mostly seniors (56%), followed by juniors (31%), sophomores (6%), and freshmen (6%), and they were majoring mostly in Construction Management (37%), Electrical Engineering (22%), and Construction Engineering (19%). Students majoring in other areas included Architectural Engineering, Civil Engineering, Electrical Engineering Technology, Energy Engineering, Energy Business and Finance, Environmental Engineering, Information Technology and Management, and Mechanical Engineering. Most respondents of the survey indicated that their faculty advisors are extremely involved (44%) or fairly involved (41%) with their chapter's activities.

Regarding the skills students expect to acquire and value the most when working with NECA student chapters (Figure 1), the one with the highest percentages of "extremely important" ratings include: network with industry members (59%), manage people and projects (53%), and learn about cost-effective, energy saving solutions (53%). When "extremely important" and "fairly important" were combined, other important skills emerged: "organize business proposals" (88%) and "apply classroom knowledge in practical problems" (81%), in addition to network with industry members (84%) and manage people and projects (81%).

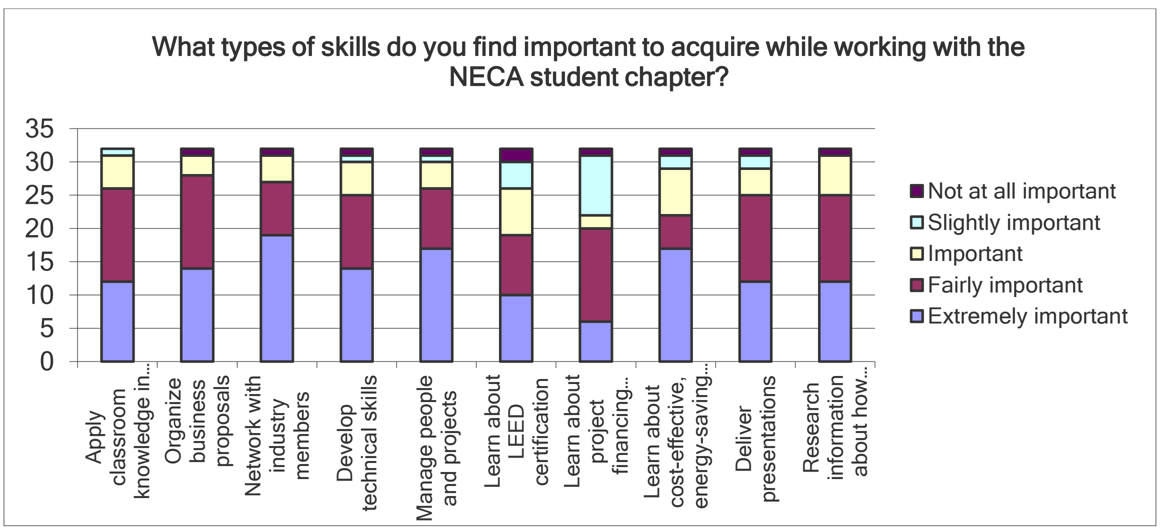

Figure 1: Skills valued by students in NECA student chapters

When asked about the skills that they are in fact acquiring while participating in NECA student chapter activities (Figure 2), students indicated that they "strongly agree" that they are learning how to: network with industry members (47%), learn about cost-effective, energy saving solutions (44%), and organize business proposals (44%). The results show a good match between the top three categories they are in fact learning from the work with the chapters (Figure 2) and what they value the most as indicated in Figure 1.

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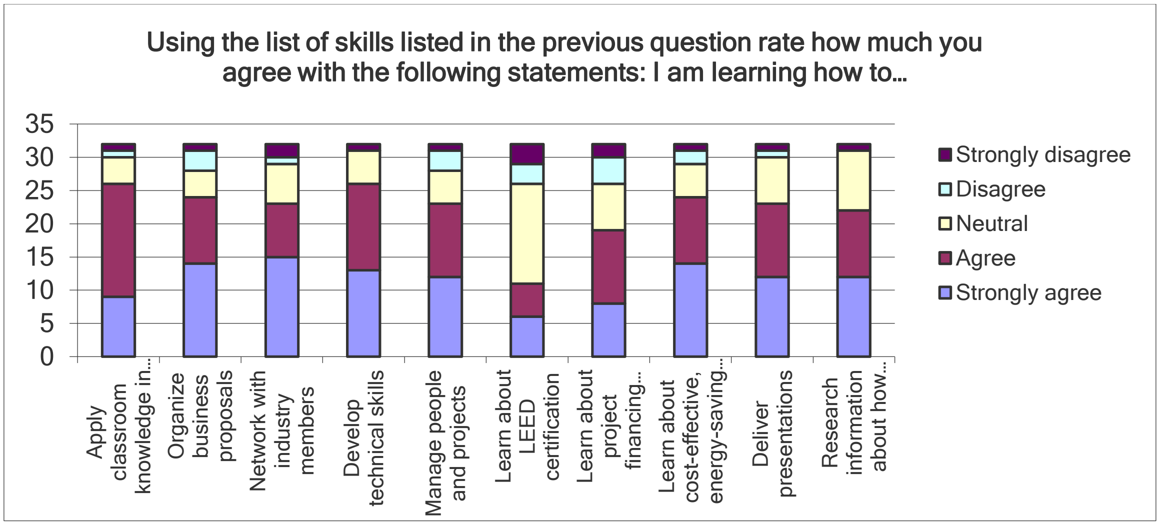

Figure 2: Skills students in NECA student chapters believe they are acquiring

Regarding the activities most often sponsored by the student chapters (Figure 3), they include: general body meetings (90%), meetings with guest speakers (78%), student competitions (65%), field visits (62%), and networking events (62%). These are activities that help students potentially acquire skills valued by the Engineer of 2020 initiative, as indicated in Table 1, including: systems thinking, global awareness and understanding, and leadership.

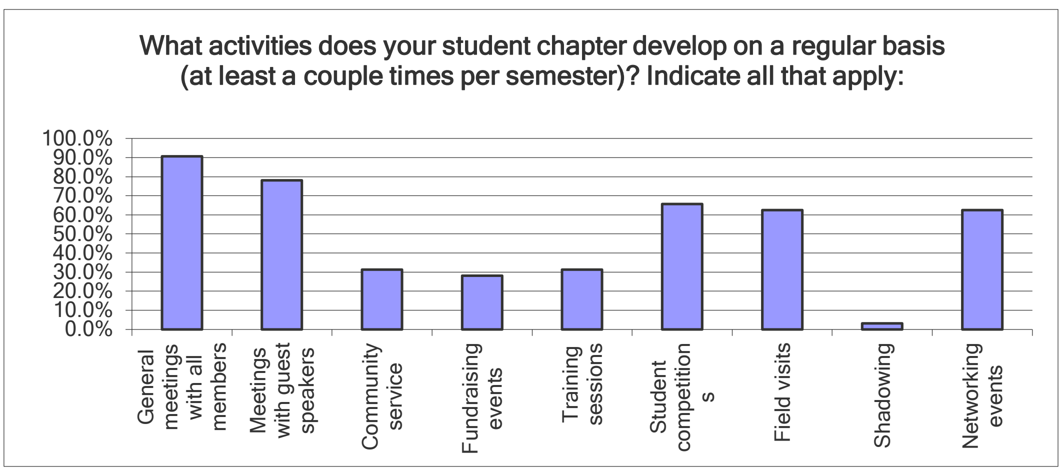

Figure 3: Activities frequently sponsored by NECA student chapters

Students were also asked about which activities they usually engage in to prepare for the Green Energy Challenge (Figure 4). The top three responses include: field visits (79%), existing coursework (63%), and internships (58%). Regarding the activities students are invited by local NECA sponsoring chapters to participate in, the top three activities are: NECA National Convention (81%), professional meetings with guest speakers (41%) ad networking meetings and events (41%). Both sets of answers indicate a strong level of interaction between the students and the local industry in different opportunities including professional meetings, field visits, and internships. Additionally, most respondents indicated that the local NECA chapter sposoring the student chapter was extremely helpful (58%) or helpful (26%) while the students were developing the Green Energy Challenge proposal.

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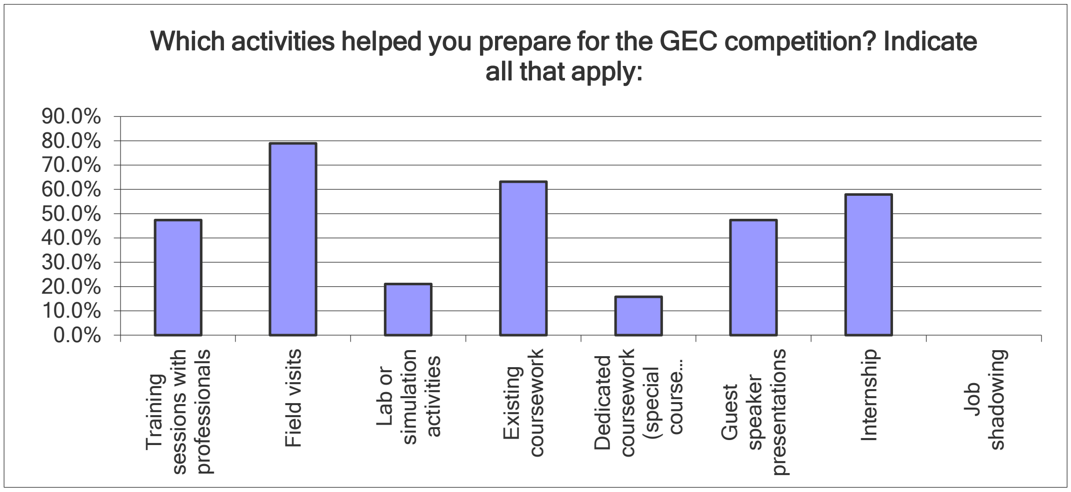

Figure 4: Activities frequently sponsored by NECA student chapters

Finally, students were asked whether they get academic credits for the work developed as part of the Green Energy Challenge competition. The results showed that only 16% of respondents got academic credits for the work developed as part of this competition, whereas 45% did not get any academic credits and 39% were not sure whether or not they get any school credit for their participation in the Green Energy Challenge. Similarly, only 13% of respondents indicated that faculty in their respective institutions allowed students to develop assignments based on the deliverables prepared for the Green Energy Challenge. These results indicate that there is a lot of room for faculty to work with NECA student chapters and allow students to get academic credits towards graduation while they participate in competitions. The academic department where the author works allows students to get academic credit for the work developed not only in the Green Energy Challenge but also in the Associated Schools of Construction (ASCE) competition and American Society of Civil Engineering (ASCE) competitions.

Synergistic potential between student chapters activities and coursework

There are numerous opportunities to support ABET student outcomes (ABET 2011)[9] using the work of student chapters. Table 2 relates ABET student outcomes to examples of student chapter activities supporting each specific outcome. If student chapter activities related to community service and competitions are incorporated into coursework, then tangible measures and rubrics used for assessing students performance can be defined to evaluate how well these outcomes are met.

The examples presented in Table 2 do not intend to be comprehensive; however, they provide suggestions on how ABET outcomes and student chapter activities can be integrated. These suggestions aim to contribute for the discussion on how extra-curricular activities can be integrated into engineering programs, and allow students to receive academic credit for the work they develop with student chapters and their sponsoring organizations.

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Table 2: ABET (2011) student outcomes and student chapter activities

ABET (2011) Student Outcomes	Examples of student chapter activities supporting the outcome
(a) an ability to apply knowledge of mathematics, science, and engineering	Participation in community work and competitions. Doing internships.
(b) an ability to design and conduct experiments, as well as to analyze and interpret data	
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	
(d) an ability to function on multidisciplinary teams	
(e) an ability to identify, formulate, and solve engineering problems	
(f) an understanding of professional and ethical responsibility	Participation in community work and competitions. Interacting with industry professionals and the community at large while trying to solve community-related problems. Doing internships. Running the chapter.
(g) an ability to communicate effectively	Participation in community work and competitions. Presenting the work developed by the chapter. Networking with industry professionals. Running the chapter.
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	Participation in community work and competitions. Doing internships.
(i) a recognition of the need for, and an ability to engage in life-long learning	Participation in training sessions promoted by the sponsoring organization. Participation in meetings with guest speakers. Networking with industry professionals.
(j) a knowledge of contemporary issues	Participation in training sessions promoted by the sponsoring organization. Participation in meetings with guest speakers.
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	Participation in community work and competitions. Doing internships.

Important activities to successfully run a student chapter

An important portion of the project about the NECA student chapters was to document how student chapters are successfully created and run by students, their faculty advisors, and the local NECA chapter sponsors. A list of tasks presented in Table 3 highlight the main tasks necessary to start the chapter, develop activities to run the chapter on a daily basis, and promote good communication between chapter members, advisors, and industry organizations. While Table 3 reflects the activities usually performed by the NECA student chapter at San Diego State University, they can be used as a baseline to start and run chapters of other engineering organizations.

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Table 3: Main tasks and activities to develop a student chapter

MAIN TASKS	SUPPORTING ACTIVITIES
Setting up a student chapter	
Define the officers	Student chapters can start with a request from the students or the parent organization that might want to start a chapter in an institution. In either case, a team of officers should be defined and be responsible for different activities as outlined in the bylaws.
Secure support to the chapter	Reach out to local members of the parent chapter and the educational institution hosting the student chapter. Prepare a budget when start-up funds are available.
Define a faculty advisor	Institutions usually require that a faculty advisor work with student chapters and supervise/facilitate their activities.
Develop bylaws	Indicate how the chapter should be run, the roles of the officers, and the required language to comply with policies of the hosting chapter and educational institution.
Running the chapter	
Organize general chapter meetings	Secure guest speakers, recruiting and informational sessions, business meetings.
Participate in/Organize sponsored events	Participate in events promoted by the local chapter (e.g., training, monthly meetings, mixers and networking events, golf tournaments, volunteer work and fundraising events).
Promoting good communication	
Use social media to publicize the chapter's activities	Create a website and pages on social media such as Facebook, Twitter, LinkedIn
Set up an email list	Use the mailing list to keep the membership updated about the chapter's events through a newsletter.
Engaging students through learning opportunities	
Promote professional development	Organize training sessions, site visits (field, office, shop), and job shadowing opportunities. Engage students in internships. Promote and support student participation in competitions.
Promote synergistic opportunities	Partner with other student chapters and campus organizations to develop activities.
Promote community service	Organize chapter-sponsored activities to promote community service, engagement, and volunteer work. Organize and/or support activities related to K-12 education to promote careers in the construction industry.
Faculty engagement	
Promote Student Engagement	Promote synergistic activities between the chapter's activities, coursework and research.
Interact with members of the parent chapter	Get updates on latest trends and needs in the industry, get support for chapter's activities, coursework, and research. Collect frequent feedback on the performance of student chapter advisors.
Participate in events	Exchange of information with other faculty advisors at the convention.
Incorporate the chapter's activities in the coursework	Allow students to develop assignments using the work related to activities and competitions the chapter participates in.

Essential to starting any student chapter is the definition of the chapter's offices, the bylaws, and a faculty advisor to work with the students and secure institutional recognition for the chapter. Additionally, the student chapter officers and the faculty advisor should seek to obtain industry support to secure funding for the chapter's activities. In order to keep the membership united in promoting the main goals of the chapter, as outlined in the bylaws and defined by the parent organization (e.g., NECA), officers should organize meetings at least once a month and bring guest speakers to help students get engaged with professionals in the industry and relate their coursework with practices in use. Another way to keep the membership engaged is to set up a

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newsletter to update students about opportunities such as meetings promoted by the parent organization, field trips, and internships.

Faculty can help the chapter, and their own program, by seeking opportunities to engage with industry practitioners and their organizations in research projects, attending networking events, and promoting interdisciplinary work among student chapters. Another important way faculty can help the chapter grow and gain recognition is to allow students to use the work developed for chapter activities and competitions as part of their coursework. Students have a chance to apply what they learn in the classroom on real world projects with tight timelines and requirements. Faculty can adapt assignments and capstone courses to allow students to get academic credit for their work as discussed before in this paper. Finally, by supporting the students and finding ways to get them engaged with student chapters' activities, faculty are promoting student engagement with professional organizations and potentially introducing students to community service and life-long learning activities.

Final Remarks

This paper presented the results of a project funded by ELECTRI International on how to successfully start and run student chapters, and promote student engagement with the chapter's activities. Initially, a literature review was presented illustrating the work of student chapters in institutions of higher education and how they support academic activities and engagement between the institutions and the industry at large. Next, a brief discussion about potential skills developed while students participate in student chapter activities was presented, followed by the feedback obtained from students about their work with NECA student chapters. Survey results indicated that students value the development of skills related to networking with industry professionals, managing people and projects, learning about cost-effective and energy saving solutions, as well as the ability to apply coursework knowledge in practical problems and develop business proposals. Students indicated that they receive good support from faculty and their sponsoring chapters, but pointed out that in most cases they do not receive academic credit for the work they develop as part of chapters' activities.

Finally, in order to highlight the work done by student chapters and how they support academic training, examples of activities that support ABET outcomes were provided. It is evident that the chapters work can be incorporated in coursework and properly assessed to support the achievement of student outcomes defined by ABET. To facilitate the creation of student chapters and the management of their activities, a list of tasks was provided with explanations on how each task can be accomplished. The author hopes that this paper contributes to the discussion about promoting student participation in student chapters and the integration of their work as an essential part of students' education in engineering programs.

Acknowledgements

The author would like to thank ELECTRI International for funding this project and NECA for supporting the important role student chapters play in undergraduate education. Any findings and conclusions presented herein reflect the author's opinions and not those of the organizations that participated in this project.

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Lessons Learned Using Mastery Learning in a Junior Level Engineering Course

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Abstract

The concept of mastery learning has been around in public schools since the 1920s (but did not gain any popularity until the 1960s). The idea behind Mastery learning is to make sure all students achieve 'mastery' of the course material by the end of the course rather than being solely concerned about assigning an A-F grade on all assignments. The driving force behind a mastery learning system is the concept that it doesn't matter *when* a student achieves mastery of the material, only that the student eventually does. The concept is akin to the cliché 'Practice Makes Perfect' in that students can keep studying/practicing the material until they master it.

The authors of this paper implemented a Mastery learning scheme in their Embedded Systems Course – a course offered to Electrical Engineering and Computer Engineering junior and senior university students. The *concept* of mastery learning was well received by both faculty and students alike, however, its *implementation* was not. We found that many students took advantage of the system to engineer their educational experience in the class to do as little as possible. This paper describes our implementation of Mastery learning and how it played out in our courses. It is our hope that this paper will give others ideas of how to learn from our mistakes so that other implementations of mastery learning schemes may be more successful.

Introduction

The concept of mastery learning has been around in public schools since the 1920s, but did not gain popularity until the 1960s, with Benjamin S. Bloom's paper on 'learning for mastery' in 1968[1] and another paper on 'mastery learning' in 1971[2]. The idea behind Mastery learning is to make sure all students achieve 'mastery' of the course learning objectives by the end of the course rather than being solely concerned about assigning an A-F grade on all assignments. The driving force behind a mastery learning system is the concept that it doesn't matter *when* a student achieves mastery of the material, only that the student eventually does. The concept is akin to the cliché 'Practice Makes Perfect' in that students can keep studying/practicing the material until they master it.

Studies have shown that mastery learning can have positive effects on student learning. A meta analysis by Kulik & Kulik[3] analyzed 40 different educational approaches and found that no other educational approach had as large a positive effect on achievement as mastery learning programs. A study by Whiting et. all[4] on 7000 high school students, also showed mastery learning increased students' test scores, grade point averages, and positive attitudes towards school and learning.

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Bloom outlined that to use mastery learning, teachers must first organize the concepts and skills they want students to learn into instructional units. After providing instruction for some time, the teacher can then administer a formative assessment based on the unit's learning goals. Instead of this assessment serving as an end to the unit, this assessment acts as an implement to provide feedback to the student on their learning. The teacher can then provide enrichment activities to those students who mastered the unit's learning goals while providing corrective activities to students who did not achieve mastery of the material. After performing corrective activities, students can then take another formative assessment that covers the same concepts and skills as the first, but includes slightly different problems or questions. This second assessment verifies whether or not the corrective activities helped students overcome their learning difficulties and offers students a second chance at showing mastery of the learning goals[5]. Figure 1 illustrates this instructional sequence.

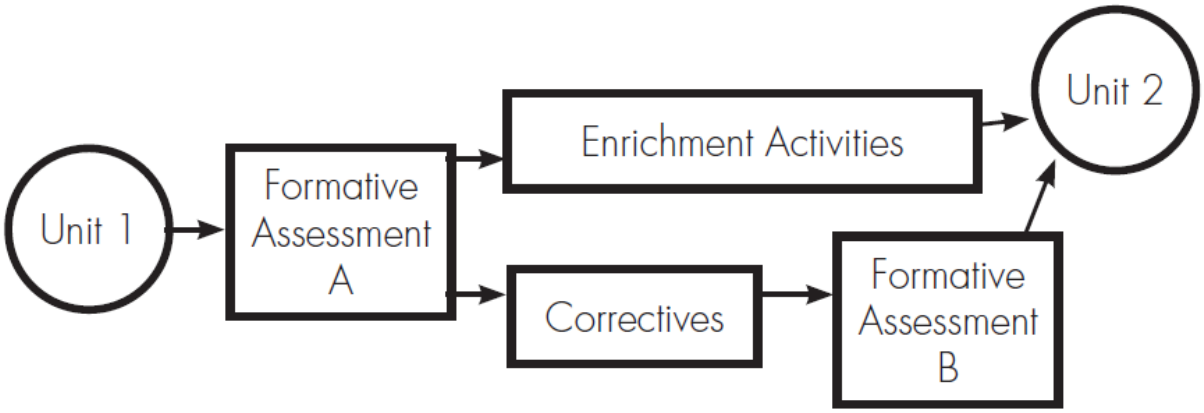

Figure 1: Bloom's Mastery Learning Instructional Sequence[5]

Although mastery learning schemes have typically been implemented in K-12 education, we decided to implement a mastery learning scheme in our junior level undergraduate electrical and computer engineering course. The rest of this paper describes our implementation of mastery learning in our course and how it played out. We conclude with a discussion of our implementation and with suggestions of how we might improve our implementation in the future.

Mastery Learning Implementation

Our course, "CPE 329: Programmable Logic and Microprocessor-Based Systems Design", is a quarter long (10-week) required upper division undergraduate course for electrical and computer engineering majors. In this course, students work in pairs in what we call a 'studio format,' where students are in the lab for a total of six hours per week, rather than having separate lecture and lab sections. The 'studio format' allows the instructor to spend as little or as much time lecturing about new topics and spend the remaining class time assisting students with their course projects. The course consists of four course projects that cover all the required learning objectives of the course.

In Spring quarter, 2014, we decided to implement a mastery learning scheme for 50% of our CPE 329 course grade. We divided up the course into two instructional units and provided a

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formative assessment of a 50-minute midterm exam for each unit. And instead of just having one re-assessment, we offered students the opportunity to retake each exam (with slightly different questions) as many times as they needed (up until the last week of class) to master (get 90% or more on) the exam. We felt this scheme more closely matched the ‘practice makes perfect’ idea, giving students more than just a second chance to succeed. Those that ‘passed’ the exams early on could use the extra time on their course projects and those that did not master the exam could use the exam as feedback to understand what types of problems they should spend more time practicing before the next exam. If the students were able to get 90% or more on both exams by the end of the class, they would automatically get 45% of their course grade, otherwise they would not pass the class. The remaining 5% of the mastery scheme was given for a mastery project, which involved having each student write a 2-3 page paper on a mastery topic of his or her choosing. The idea behind this mastery project was to provide every student (and not just those that mastered their exams on the first try) with a mastery enrichment activity.
The remaining 50% of the course grade was graded using a traditional point based grading system where the four course projects counted for 20% of the grade and the final exam counted for 30% of the grade. We did not use a mastery scheme on these aspects of the course as course projects were mostly graded on the completeness of the specified design and the final exam was meant to be a final summative assessment tool to determine that the students did indeed ‘master’ the course. The grade distribution for our CPE 329 course can be seen below in Figure 2.

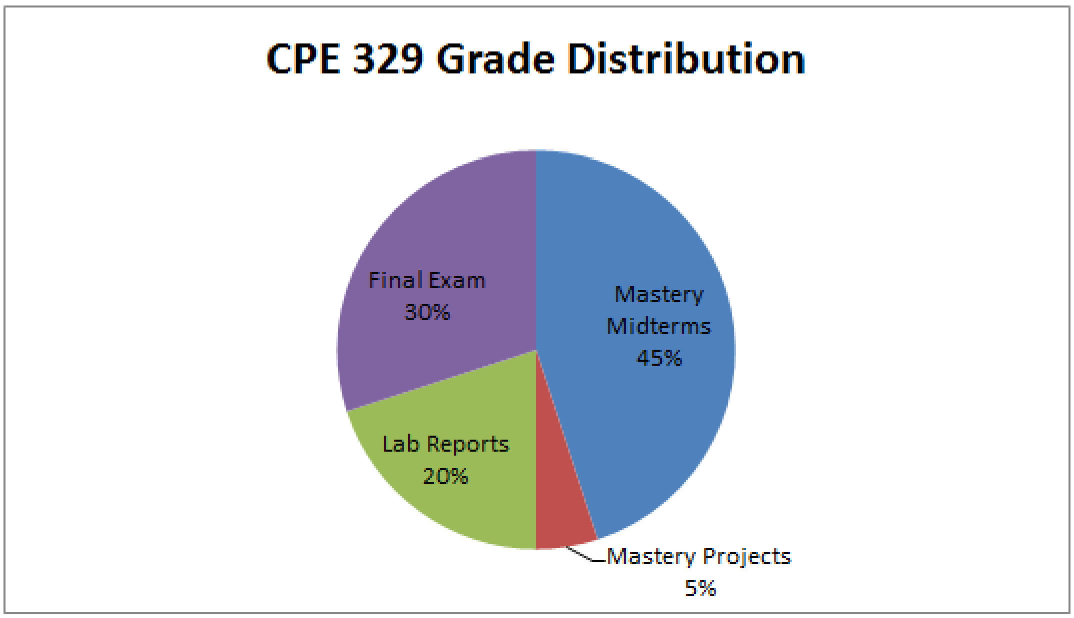

Figure 2: CPE 329 Grade Distribution

We expected our mastery learning scheme to be well received by students and instructors and to accomplish the intended goal of increased mastery of the course learning objectives for all students. Unfortunately, our implementation did not play out as expected.

How it Played Out

On the first day of class, when we presented our mastery learning scheme to our students, it was well received. All students liked the idea of being able to re-take exams to mimic the ‘practice-

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makes-perfect' mentality and were confident that they would be able to 'master' the course learning objectives by the end of the course under our mastery learning policy. However, as the quarter progressed, students and faculty began to have different sentiments about the policy.

High Achieving Students

Students who mastered the exams on the first try did not see any difference between the mastery learning approach and a traditional point based learning approach. Some of the students in this category actually started to dislike the 'mastery learning' scheme as the exam retakes for the other students started taking up some class time that they could have otherwise used for course projects. Although they were encouraged to work on projects outside of class during this time, some students lacked the motivation to do so. Some students in this category also started becoming resentful of those who needed to retake the exams because they felt it unfair that 'lower performing' students might end up doing better than they on the final exam due to having had more exam practice.

Medium Achieving Students

Students who came close to mastering the exam would be the most likely to argue for a few more points on the exam to push them over the 'mastery' threshold. They resented 'just missing the mark' and felt it was unfair that they had to retake the exam when they 'were so close.' Many students in this category felt it was unfair that they were 'lumped' into the same category as those that performed very poorly on the exam. They viewed the ability to retake the exam as a punishment rather than an opportunity. Most of them said they would have been satisfied with the traditional point based grade and would have preferred spending their time studying for other courses rather than 'wasting' time studying to 'master' the exam for this course.

Low Achieving Students

Students who did poorly on exams multiple times were very happy to have the opportunity to retake exams, but ended up taking advantage of the system to do as little as possible. Instead of using the exam as feedback to illustrate areas of weakness and spending time to 'correct' those errors through further practice, some students showed up to exam retakes without ever having looked at their first exam. Some students acted as exam 'tourists,' previewing the exam retake to see if was one they would like to take and turning it in blank if they just didn't feel like taking it. Some students re-took each midterm exam seven times and a few of these students never 'mastered' the exams. However, the few students in this group who did treat the learning process seriously, did benefit from the mastery learning process and greatly appreciated the instructor's time and effort to assist them with learning the material.

Instructors

The instructors of the course found the 'mastery learning' policy to be exhausting. Each week, the instructors had to create, administer, and grade exam retakes. To try and minimize losing class time for exam retakes, the instructors scheduled and administered some of the retakes outside of class. By the 5th first midterm, the instructors became very discouraged and felt like most students were wasting the instructors' time when they found students not even trying to improve with each subsequent retake. The instructors also did not have the heart to automatically fail students who did not 'master' the exams by the end of the course as the students did

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complete all the course projects and may have passed the class if it had followed the traditional point based grading policy.

Performance

To see if our mastery learning policy had the effect of increasing mastery of course learning objectives for all students, the instructors compared the final exam grades of the students in CPE 329 for Spring 2014 (where the mastery learning policy was used) and CPE 329 for Spring 2013 (where a traditional point based grading policy was used). The instructor, final exams, and class size (n=32) were the same for both years. The final exams were curved to have an average of 76.8%. Figure 3 shows the percentages of As, Bs, Cs, Ds, and Fs received on the final exam for each style of course. From Figure 3, we see there was a higher percentage of As and Bs in the traditional style course than in the mastery learning course, suggesting that our mastery learning scheme did not produce the intended outcome of having more students master the course concepts.

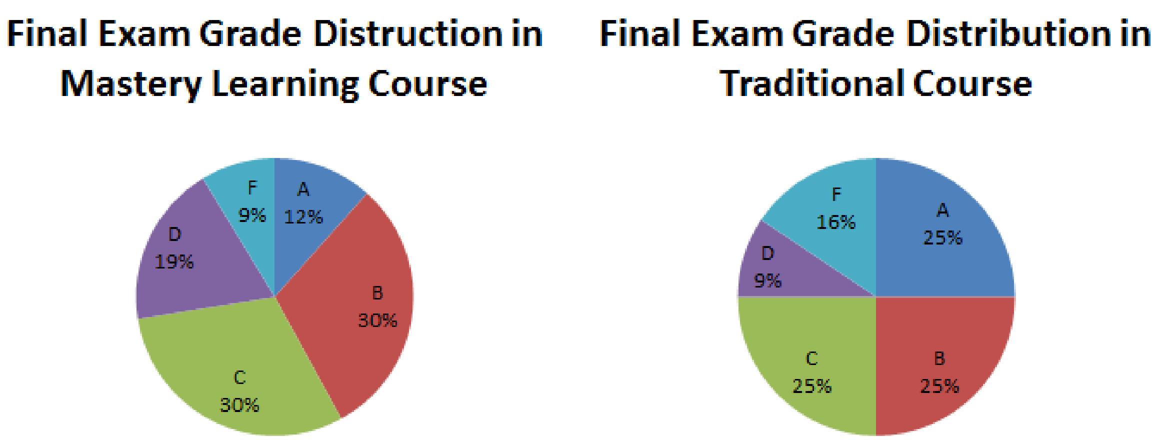

Figure 3: Course Grade Comparison between Mastery Grading and Traditional Grading

Discussion

From the experience, we learned that our implementation of mastery learning - offering the opportunity to retake midterms over and over again - did not have the effect we had hoped for. Instead of being well received by students and faculty and providing a higher level of mastery for all students, our implementation was poorly received by students and faculty and showed a lower level of mastery for most students. We can likely attribute much of this outcome to the following:

Poor use of corrective actions

We relied heavily on the students to determine their own corrective actions. We expected the students to review the mistakes they made on each midterm exam and come to office hours or spend extra time outside of class to figure out how to correct those mistakes so they wouldn't make the same mistake again on the next retake. However, a student who doesn't spend time studying or asking for help in the first place is likely to not study or ask for help again. Specific, targeted, corrective action (such as asking students to turn in extra practice problems related to

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the problems they got wrong on the exams) may have been a better means to provide needed correction.

Poor use of class time
Administering exam retakes in class turned out to be a poor use of class time as it made students conducting enrichment activities on their projects feel less important. Classtime could perhaps be better spent on guided corrective and enrichment activities rather than on continued re-assessments.

Competition with other courses
When other classes students are taking are using a traditional point based grading system, students will give priority to studying for their other classes (in fear of getting a bad grade) instead of for a class that allows continuous exam retakes. Students had little incentive to spend time studying for an exam that they knew they could just keep retaking in the future.

Limited time in the quarter
In a quarter system, where an A-F grade is required for the student's transcript at the end of only 10 weeks, it is impossible to implement the intended spirit of mastery learning - the concept that it doesn't matter *when* a student achieves mastery of the material, only that the student eventually *does*. The fact of the matter is, students do not have all the time in the world to master a concept, and for some students, 10 weeks may just not be enough time to achieve mastery of all the course's learning goals.

Conclusion

Although our implementation of mastery learning did not play out as we anticipated, we are still intrigued by the concept and hope to try a revised implementation in the future. Next time, we plan to stick more closely to Bloom's mastery learning technique (Figure 1) and spend more time on guiding corrective actions and enrichment activities and providing only one secondary assessment.

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Cooperative Learning of Nanomaterials Manufacturing and Characterization through High Impact Practices

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Abstract

High-impact practices such as first-year seminars, learning communities, service learning, undergraduate research, and capstone experiences are effective on enhancing learning. In this paper, we will present how to improve undergraduate student education through high impact activities in a cooperative learning setting. Specifically, scalable, low cost manufacturing process for making high performance energy conversion nanomaterials is dealt with. Cooperative learning on several upper division general engineering courses including Independent Research and Studies, Senior Capstone Design, Special Topics on Nanotechnology is investigated. Several scalable, low cost manufacturing research tasks are adopted to enhance the context learning through cooperative learning approach that integrates advanced manufacturing research activities into both academic and social learning experiences. Team-based research projects are implemented. Meanwhile, structuring positive interdependence of students is emphasized. The main content includes: (1) low cost, scalable manufacturing process leading to various nanomaterials research, (2) nanomaterials property characterization, and (3) cooperative learning effectiveness evaluation. The paper addresses fundamental issues including how to allow undergraduate students learning better through cooperative learning approach, how to effectively develop workforce in several priority fields in this country such as advanced manufacturing and nanotechnology, and how to end social inequality in engineering education and practice. The research work focuses on low cost, scalable nanomanufacturing. Nanoporous materials, electrospun nanofibers, and nanoparticles for energy conversions are studied. Students learn multidisciplinary science and engineering knowledge through four focused research projects i.e. (1) nanoporous materials processing and characterization, (2) nanomaterials for energy conversions, (3) nanofibers for photoelectrochemical energy conversion and (4) superparamagnetic nanoparticles for biomedical applications including high resolution magnetic resonance imaging and hyperthermia therapy. Synthesis of nanoporous materials with high surface area for nanosensor applications was performed. The morphology of the nanoporous materials was characterized. Self-assembled nanostructures for energy conversion were investigated. Multilayered structures containing nanoarchitectured fiber arrays were designed and fabricated. The structures are capable to absorb solar rays, and convert the radiation energies into heat and electricity. Students also learned how to make photochemical catalysis electrode. Fundamentals of oxide materials’ response to external magnetic field is studied to explore new biomedical imaging agents with controlled nanostructures. Synthesis of superparamagnetic oxide multilayer nanotubes with enhanced hyperthermia was performed. Evaluation on the learning outcomes is provided. Both formative evaluation and summative evaluation results are presented to support the collaborative learning.

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Introduction

In next decade, over millions of undergraduates will be trained in engineering fields all over the country. It is, therefore, imperative to implement effective learning methodologies to enhance education in engineering. Nanomaterials and related manufacturing technology with the multidisciplinary nature are viewed as important areas in engineering filed. Universities should provide students in-depth knowledge and opportunities and allow them to practice multidisciplinary concepts and team working. The cooperative learning setting may allow students to enjoy unique learning experience. Since the industry and academia require students with both practical and analytical skills, undergraduate student learning through the exposure of scientific research is adopted. The pedagogical effort focuses on knowledge obtaining and skill acquiring.

In this work, we practice the project-based cooperative learning. The learning context includes experiments to address nanomaterials synthesis, nanomanufacturing processes, and characterization. Such an approach is implemented in a wide spectrum of upper division courses including the Independent Research/Study, Nanotechnology, and Senior Capstone Design.

Cooperative Learning Context

The cooperative learning was conducted through several small research projects. In the first team project, the development of a nanomaterial sensor using a quartz crystal microbalance (QCM) to determine the concentration and the rate of decomposition of ammonium nitrate (NH_4NO_3) in water is performed. Results are presented for the sensor readings for dilute solutions of ammonium nitrate (NH_4NO_3) in various concentrations. The participating students show a very good correlation of concentration level with the output response of the QCM. The students also find that QCM is very sensitive to the scan rate of the voltage potential.

Ammonium nitrate has long been used as a high nitrogen fertilizer in the agriculture industry. In the 1950’s it was discovered that ammonium nitrate mixed with fuel oil (ANFO) provided an excellent explosive that could be used in the mining industry. Since ANFO and ammonium nitrate are so commonly used in industry, there have been several instances of accidents and malicious use. The most notable malicious use of ammonium nitrate as an explosive for a terrorist attack was the 1995 Oklahoma City Bombing. In order to reduce the danger associated with this chemical there needs to be a reliable method to detect and determine the concentration of ammonium nitrate.

One possible method to detect ammonium nitrate is through the use of an electrochemical quartz crystal microbalance. A QCM is a sensor composed of a thin slice of a single crystal of quart between two gold electrodes which resonates at a known frequency. When the crystal is in contact with a solution, the molecules that are dissolved in the solution can deposit themselves on the surface of the crystal and cause a change the resonating frequency which can be measured and recorded. A QCM has been used previously in experimentation to detect gaseous ammonia (NH_3) in the air[1]. Most of the research before 1980 involving QCM sensors was conducted in a vacuum environment and used for the detection of gasses. In the 1980’s there are several

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examples of experiments successfully being conducted with the QCM in contact with liquids[2]. There have also been successful experiments using a QCM to determine the concentration of methanol (CH_3OH) in liquid form[3]. The purpose and scope of this experiment was to determine a method for explosive detection and mitigation using a QCM as a sensor. The QCM is used in conjunction with two electrodes supplying varying voltage potential to the solution of ammonium nitrate to cause decomposition. There have been other methods of decomposing ammonium nitrate which require significant temperature and pressure to sustain[4]. This experiment attempts to use electrical potential along with a platinum electrode as a catalyst to cause decomposition of the ammonium nitrate.

The students designed an experimental approach for explosive detection and mitigation using quartz crystal microbalance (QCM). The purpose of this experiment was to do explosive detection and mitigation using a QCM as a sensor platform. The QCM is used in conjunction with two electrodes supplying varying voltage potential to the solution of ammonium nitrate to cause decomposition of the explosive. There have been other methods of decomposing ammonium nitrate which require significant temperature and pressure to sustain. This experiment attempts to use electrical potential along with a platinum electrode as a count electrode to cause decomposition of the ammonium nitrate. The experimental procedures are fairly simple and the equipment and solutions used for this experiment included:

1. Electrochemical Analyzer – CH Instruments Model CHI440C
2. Quartz Crystal Microbalance (QCM) oscillator
3. Aqueous ammonium nitrate solutions in 0.1 M, 0.5 M, and 1.0 M concentrations
4. Platinum electrode
5. Reference electrode – Silver/Silver chloride (AgCl) in KCl

Three samples of ammonium nitrate with varied concentrations were prepared for this experiment. Approximately 20 mL of each sample was tested individually by putting it into the QCM test cell. The QCM test cell consisted of the plastic housing to hold the solution and the quartz crystal inside and ports to connect the QCM to the analysis equipment. The Platinum electrode was inserted into the solution and connected to the voltage supply. The silver reference electrode immersed in silver chloride was also inserted into the solution and connected to the opposite lead of the voltage supply. For this experiment an electrochemical analyzer (CH Instruments Model CHI 440C) was used to set the parameters of the testing and for data acquisition. See *Figure 1* for experimental set-up.

For each concentration of ammonium nitrate and the control (de-ionized water) the voltage potential was scanned between 0 volts to 0.5 volts and back to 0 volts in a cycle. The time interval between each incremental voltage change was also independently varied to later determine the time effect and response of the sensor. The parameters of the testing along with the corresponding ammonium nitrate solution concentrations are shown in *Table 1*. The current response was measured and recorded with the corresponding potential. The change in frequency of the QCM was also measure and recorded.

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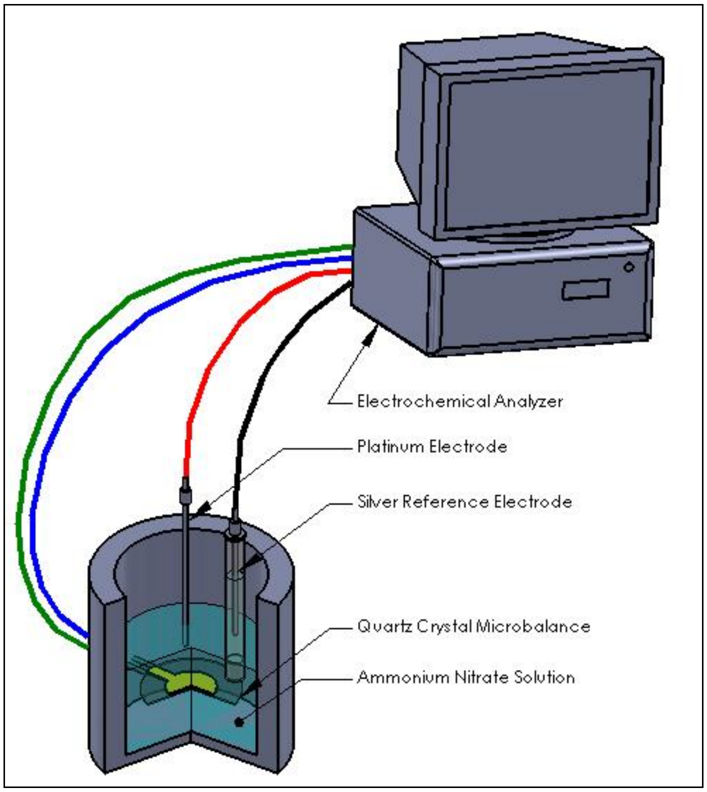

Figure 1: Experimental set-up

Table 1: Test parameters and ammonium nitrate solution concentrations

Concentration (M)	0.5	0.1	0.1	0.1	0.1	0.1	1.0	1.0	1.0	water	water	water
Init E (V)	0	0	0	0	0	0	0	0	0	0	0	0
High E (V)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Low E (V)	0	0	0	0	0	0	0	0	0	0	0	0
Scan Rate (V/s)	0.01	0.1	0.01	0.005	0.001	0.001	0.1	0.01	0.001	0.1	0.01	0.001
Sample Interval (V)	0.001	0.01	0.01	0.01	0.01	0.01	0.01	0.001	0.001	0.01	0.001	0.001
Sensitivity (A/V)	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06	1.0E-06
QCM Init Freq (Hz)	7864227	7842048	7834305	7852789	7813336	7816129	7982896	7982881	7982783	7865140	7864816	7818423

Figure 2 shows the results of the experiment with each concentration of ammonium nitrate and water samples. As the voltage potential was varied from 0 to 0.5 volts and back to 0 volts the natural resonance frequency of the QCM increased both during the rising voltage potential and during the falling voltage potential interval. It is also clear from *Figure 2* that with each concentration of Ammonium Nitrate there is a distinct shift in the change in frequency. As the concentration is stronger the natural frequency becomes lower relative to the natural frequency of the crystal in water. This phenomenon is caused by the increased density of each more concentrated solution. Since the density is higher with higher concentrations, the thin film of solution that is in contact with the crystal also has a density and reduces the natural frequency of the crystal.

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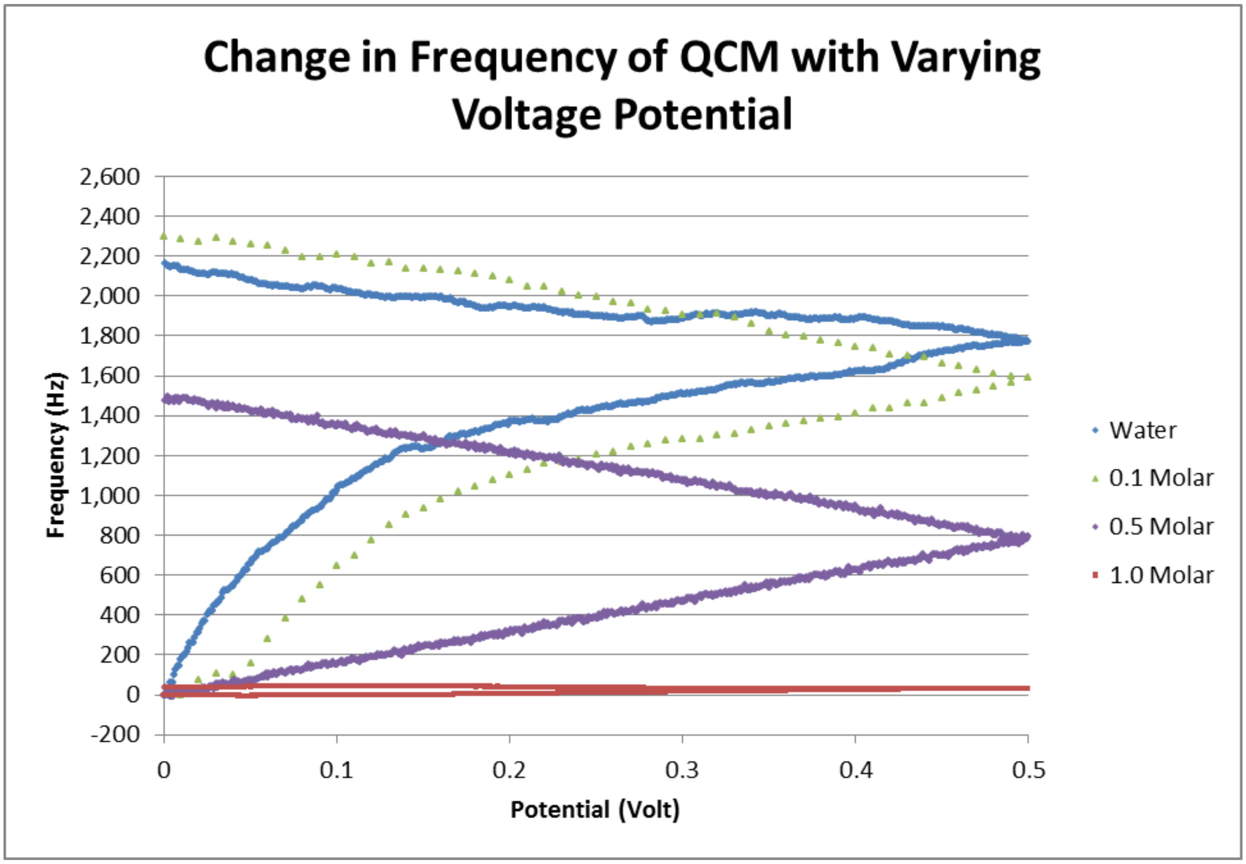

Figure 2: Change in frequency of the QCM measured with varying voltage potential for different concentrations of ammonium nitrate

From the data it appears that initially the change in frequency is increasing logarithmically with a very rapid increase at first and gradually trending toward a steady frequency. This trend can be more easily seen when the frequency change is plotted against the time duration of each experimental analysis.

As a concluding remark, this experiment was a successful test of sensing ammonium nitrate in liquid form using a QCM as the sensor platform. There were clear frequency changes or shifts that could be used to determine the concentration with proper calibration. There are also several limits to this technique of sensing including the rate of voltage potential scanning has a significant impact on the resulting measurements. The clearest most distinct trends occurred with the slowest scan rates for the voltage. There did not seem to be measurable difference in concentration caused by decomposition induced by the potential and the electrodes. This could be due to the small scale of the experiment. Future testing could be conducted using constant voltage and measuring the variables against time to get more steady results. Also acquiring a larger sample size would be beneficial in determining stronger correlations.

The second project is on electrospinning nanofibers for medical applications. Electrospinning has been researched for the past thirty years. In its growth, it uses in the electrical field with sensor materials; the medical field with tissue scaffolding as well as drug delivery. As shown by Sill and von Recum's research, by attaching specific proteins to electrospun matrices, they were able

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to help with decreasing the spreading rate of an infection[5]. The research with electrospinning continues today with its growing applications across many engineering practices. The purpose of this project was to produce a quality, electrospun fiber that would later lead to possible medical applications. There are needs for drug delivery in which manufacturing the product may be difficult. Electrospinning offers one method in which nanofibers are relatively easily produced and very helpful in drug delivery. On the same note, producing nanofibers can also create small meshes of grafts that can react to external energies such as microwaves. With the right materials, a microwave can cause a reaction and by design activate the nanofibers. This is the main goal of the project. The experiment will begin with spinning iron based nanofibers with other materials, and observing its reactions to external electromagnetic waves.

The first material tested was the polyvinylpyrrolidone (PVP) solution. The samples were used as the baseline control group of the experiment. Ethanol alcohol was mixed with 10% PVP synthesizing approximately 5 mL of the solution. It should be noted that a small trace of food coloring was added to the control solution so that the fibers would later be easily observed. The PVP solution was poured into a 10 mL syringe using a 24 gage needle. In the second test, a second batch of PVP and ethanol was prepared with the addition of 0.1 g of pure fine iron. To thoroughly mix the solution with the iron particles, an ultrasonic processor was used. Due to the grain size and viscosity of the second and third solution, a larger 22 gage needle would be used on a 1 mL syringe. There was some concern in the possibility of a particle clogging within the syringe during the electrospinning. Lastly, for the third test 0.1 g of iron and 0.05 grams of oxide powder were added to the 1 mL of PVP ethanol alcohol solution. It should be noted that although oxide was added for the third test, a similar gage needle was used as in the second test. The third solution was not mixed with the ultrasonic processor, but plainly mixed by thoroughly stirring.

The solutions were prepared in small glass beakers. Upon mixing the samples, the solutions were poured into their respective syringes which would be later inserted into the medical pump. The Chemyx Fusion 200 Classic syringe pump was chosen due to its precise control of flow rate. For this experiment, there were occasions where a flow rate of .001 mL/min was desired and was easily achieved due to the syringe pump's wide range of speeds. The syringe pump was then placed on top of a stable metal stand. Once the syringe was securely clamped into the pump, the receiving plate was placed approximately 7 to 9 cm directly in front of the syringe. Two glass slides were placed over a paper towel on the receiving plate to act as targets and collectors catching the spinning fibers. With the receiving plate being mounted to a vice, the glass slides were held in place, clamped by magnets.

The next step was to then set up the electrical system. The electrical components consisted of a RSR DC Power Supply which was connected to a Hewlett Packard E3615A Power Supply then connected to the CZE2000. The CZE2000 was used as a magnifier to increase the power to the needed 15 kV. The positive end of the power supply was connected to the needle of the syringe and the ground end was connected to the back of the receiving plate. Careful precautions were taken to minimize any risk of the wires shorting on the metal stand or the ground. The positive wire was connected to the syringe tip while the negative, ground end was connected to the back of the receiving plate. This enclosed the magnetic field which would provide the bridge for the fibers to move across.

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Table 2-A through 2-D show the temperatures recorded as well as the changes in temperature with respect to the given time affected by microwaves. While ethanol alcohol was present during the synthesis of all solutions, with the process of electrospinning the alcohol actually gasifies and evaporates. Thus the liquid should theoretically have no effect in the microwaving process. The temperature ranges were normally within 3 degrees of the average. The data curves show that the nanoparticles of the iron and oxide do have thermal effects on the fibers. The temperature effects are not drastically different from the control temperatures. In comparison to the PVP the test fibers lost around 20%- 30% in heat gained through the microwave.

Table 2-A: Control substrate test results

Control: Glass Plate							
Time (s)	Temperature (˚C)					Avg T (˚C)	ΔT (˚C)
0.0	22.0	22.0	22.0	22.0	22.0	22.0	
5.0	23.2	23.0	22.0	23.0	23.2	22.9	2.6
10.0	25.4	26.0	25.8	25.8	26.6	25.9	5.7
15.0	28.6	28.8	30.0	28.4	28.2	28.8	8.6
20.0	35.0	35.6	35.6	34.6	36.0	35.4	15.1
25.0	41.0	45.0	46.0	45.0	41.0	43.6	23.4
30.0	45.0	48.0	46.0	42.4	43.0	44.9	24.6

Table 2-B: PVP nanofiber responses

Test 2: PVP							
Time (s)	Temperature (˚C)					Avg T (˚C)	ΔT (˚C)
0.0	22.2	21.0	22.0	21.8	21.8	21.8	
5.0	23.0	21.8	24.0	24.0	23.6	23.3	3.0
10.0	25.8	25.2	24.3	26.6	26.2	25.6	5.4
15.0	37.0	38.0	36.0	37.2	37.8	37.2	17.0
20.0	40.6	41.0	39.8	41.0	40.6	40.6	20.4
25.0	49.0	49.2	49.2	49.0	48.8	49.0	28.8
30.0	47.6	47.0	45.6	47.6	48.0	47.2	26.9

Table 2-C: Iron particle-containing PVP nanofibers

Test 2: PVP + Fe							
Time (s)	Temperature (˚C)					Avg T (˚C)	ΔT (˚C)
0.0	21.8	21.8	21.8	21.8	21.8	21.8	
5.0	22.6	22.8	20.2	22.2	22.2	22.0	1.8
10.0	26.0	24.8	25.0	25.0	25.0	25.2	4.9
15.0	32.0	30.4	31.2	29.8	30.0	30.7	10.4
20.0	34.0	33.0	33.8	32.2	33.8	33.4	13.1
25.0	36.8	37.4	38.6	37.2	36.6	37.3	17.1
30.0	39.0	42.0	41.6	38.0	40.0	40.1	19.9

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Table 2-D: Iron oxide containing PVP nanofibers

Test 3: PVP + Fe + O							
Time (s)	Temperature (˚C)					Avg T (˚C)	ΔT (˚C)
0.0	20.0	19.6	19.6	19.6	19.6	20.2	
5.0	20.6	19.8	20.8	20.0	20.0	20.8	0.6
10.0	21.4	20.0	21.0	20.8	21.0	23.7	3.4
15.0	25.0	24.8	22.0	23.0	23.6	33.9	13.7
20.0	33.6	34.0	33.6	33.6	34.8	33.9	13.7
25.0	36.6	35.6	36.2	35.8	36.4	36.1	15.9
30.0	36.6	35.2	36.8	36.4	37.0	36.4	16.2

The results confirm that it is definitely possible to use electrospinning to produce iron-containing nanofibers as opposed to other techniques. If these materials were to be used to produce a mesh that can be placed within the human body, its properties can react to a magnetic field produced by an magnetic resonance imaging (MRI) machine which would be useful in future applications.

Evaluation on the learning outcomes

Evaluation on the learning outcomes is conducted. Both formative evaluation and summative evaluation were made to examine the effectiveness of the collaborative learning. By the time of finishing the team projects, two of the students have been on the full time positions. One was accepted by graduate program and started the Master Degree project. One student is at the senior level and will continue his capstone design project on the similar topic. The team projects helped three students to meet the requirements of the graduation and obtaining the BS degrees.

Conclusions

Undergraduate research and capstone experiences are effective on enhancement of learning. Improving undergraduate student education through high impact activities in a cooperative learning setting is a way worthy of exploring. Specifically, scalable, low cost manufacturing process for making high performance energy conversion nanomaterials is dealt with in our studies. Cooperative learning on several upper division general engineering courses including Independent Research and Studies, Senior Capstone Design, Special Topics on Nanotechnology generates the outcome of improving the graduation rate. Several scalable, low cost manufacturing research tasks are adopted to enhance the context learning through cooperative learning approach that integrates advanced manufacturing research activities into both academic and social learning experiences. The student groups enjoyed the team-based research projects and generated meaningful results.

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Teaching Brain-Inspired Visual Signal Processing via Undergraduate Research Experience

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Abstract

Brain holds the mystery to future intelligent systems. The efficiency of brain in visual signal processing is unparalleled by any computers of today. The underlying process preformed on the visual input from the eye is edge detection at the primary visual cortex which is then used for object recognition at deeper layers. Designing a signal processing unit that mimics the organization of the brain with the anticipation of gaining the benefits of the brain's performance is referred to as brain inspired approach. Engineering undergraduate students do not get to experience a brain inspired approach to signal processing unless they take a course on artificial neural networks and such courses often teach abstract concepts without offering students an opportunity to really build a working design that is truly brain inspired. We aim to address this gap via a research experience program during which undergraduate students in a team perform the task of designing a brain inspired neural network for edge detection and test their design using a real live camera feed to their system and producing a live video display showing the detected edges. The design involves modeling and implementation of simple and complex neural cells for edge detection along four orientations of 0, 45, 90, and 135 degrees. The simple cells are modeled by Gabor filters and complex cells by a max pooling approach. The models are implemented in Matlab environment and a webcam is used to obtain a live visual input for testing. The internship is planned over 10 weeks and the intern students are assigned a graduate student mentor. This paper presents the details of the project, research and educational objectives, results obtained, and the student surveys assessing the outcomes.

I. Introduction

The purpose of this research project was to develop a software-based model, with hardware implementation capabilities, of a brain-inspired neural network responsible for edge and orientation detection. Consequently, we had to validate the developed model through extensive testing, using diverse environments that might affect the functionality of the model—for instance, the use of fixed images initially, and then, the incorporation of live streaming video. For such testing we used different geometric objects like squares, right triangles, circles, as well as a more complex image like a picture of Lenna Gray (used to test image processing software).

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Furthermore, changes like the lightning setup, background and the filling of the shapes in addition to 2-D and 3-D shapes were included in the second phase of the testing process.

During the summer internship period, we were able to develop a software-based model of visual neocortex using MATLAB which is a programming language with significant capabilities for image processing. Our model was able to recognize several edges and orientations at a time; it could easily be implemented in hardware to expand its efficiency and simulate better the biological brain function. The development of this model could also aid in creating more efficient pathways to other related systems. These systems could be beneficial in other fields of research such as medical, consumer, industrial, transportation, and military applications.

II. Biological Background

Artificial neural networks are computational (hardware/software) circuits developed to mimic a biological neural network. Biological neural networks are formed by thousands of neural cells interconnected and specialized in different brain functions. This research project was focused on the development of an artificial neural network mimicking the primary visual neocortex responsible for edge and orientation detection. This research will result in a more efficient simulation of the brain function for object recognition. In order to develop such a model a better understanding of the biological brain function for edge and orientation detection is needed.

Edge and orientation detection are basic functions needed for object recognition. For instance, before recognizing a square the brain detects the four edges with similar lengths and their orientations. As was mentioned before, there are different kinds of neural cells that are responsible for specific functions. In the case of edge and orientation recognition, David Hubel's and Torsten Weisel's experiments and proposals show that the process starts in the eye where Photoreceptor Cells are stimulated by light. Other cells within the eye are responsible to carry these stimuli to Retinal Ganglion Cells (RGC). At this stage "retinal ganglion cells respond to contrast in their receptive field. On-center ganglion cells are excited when stimulated by light in the center and inhibited when stimulated in the surround; off-center cells have the opposite responses"[4]. Up to this point all the cells involved in object and orientation recognition are located in the eye, while the next stage is the transmission of the stimulus to the brain.

Simple and Complex Cells are found in the primary visual cortex located in the occipital lobe of the brain (refer to Figure 1). Simple Cells are sensitive to edges with specific orientations. When a simple cell is fired the stimulus will be sent to a complex cell which is also sensitive to edges with specific orientations but with a degree of spatial invariance. Thus, a complex cell has a greater receptive field and can detect multiple edges with the same orientation independently of its location. Hubel and Weisel proposed the existence of feed-forward networks "where concentric circle cells of one orientation, make excitatory connections with simple cells of the same orientation, and simple cell outputs make excitatory connections with a complex cell tuned to the same orientation to detect a specific orientation of light"[1]. Our research project was based on this network feed-forward concept concentrating on the function of the most significant cells: photoreceptors, ganglion, simple, and complex.

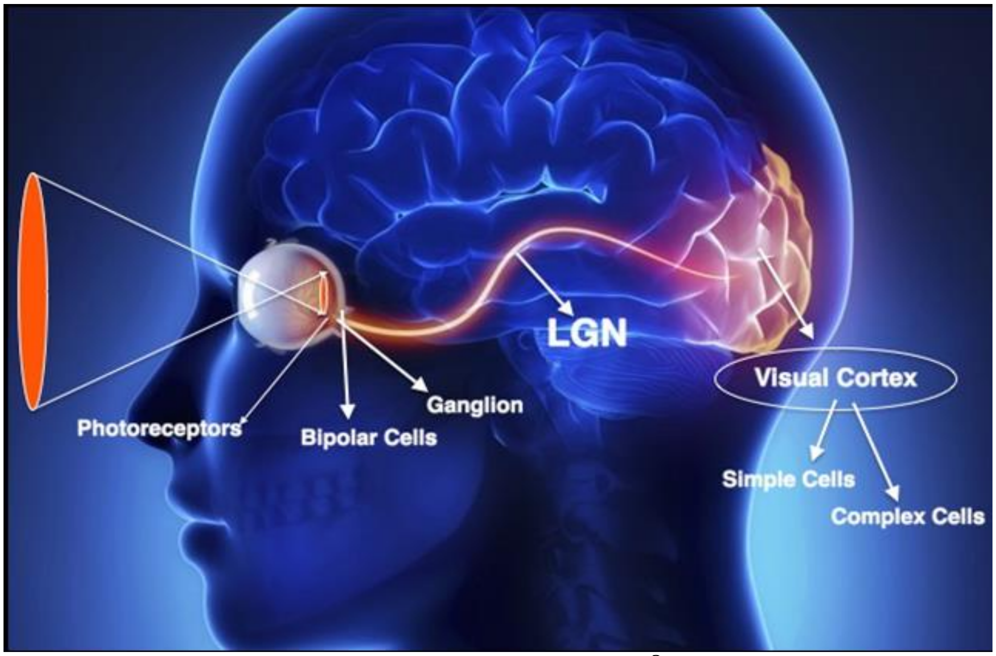

Figure 1. Primary Visual Cortex[2]

III. Functions of Model

In order to simulate the biological brain process for edge and orientation recognition, we processed the image data by passing it through various functions modeling various processing happening in real visual neocortex. Figure 2 shows the Main Loop Algorithm of our software model. The first stage, which starts in the eye, is represented by the webcam. The webcam is able to capture the image and represent it as pixel values; for our program we used greyscale (greyscale values range from 0 or black to 255 or white). The use of grayscale values simplifies the image processing, especially for edges, and accelerates the processing time. Each pixel represents a photoreceptor cell which is stimulated by light, once the photoreceptors are stimulated ganglion cells receive the signal to be processed. When an image frame is read from the camera, the grey scale values are stored in a 2-D array and the information is sent for processing to the Ganglion and Simple Cells. These two stages are combined into the Gabor Filter Function in our program; the Gabor Filter Function is explained in detail in the Gabor Filter: Ganglion Cell and Simple Cell section of this paper. Once the image array is processed by the Ganglion and Simple Cells, the output arrays are sent to the Complex Cell Function to determine the total orientations and edges detected independently of location on the input image frame. It is important to mention that the output of this program is four 50x50 value arrays, one per each orientation (0, 45, 90, and 135 degrees). In order to easily visualize the results, the output is shown as an image plot.

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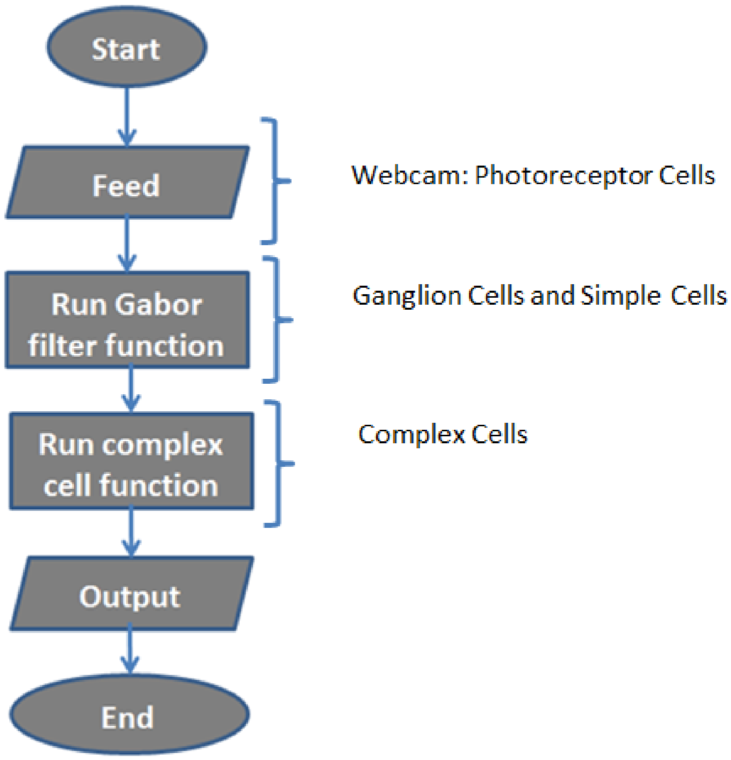

Figure 2. Main Loop of Software Model

A. Camera Function: Photoreceptor Cells

In our program the webcam represents the eye. Since the image is captured and stored as pixel values, the pixels represent the photoreceptor cells in the eye which are passed and processed by the Gabor Filter and then the Complex Cell as well. The application we used for the webcam was MATLAB because it is friendly for image processing. In order to start the webcam a video input object is created and then the webcam properties are changed to greyscale for faster processing. Afterward, the video-input object is started to obtain image acquisition for the webcam and temporarily paused for easier processing. After completing these steps, a “while loop” is used to repeat the statements in the code while obtaining and processing individually each image frame captured. The input frame is resized to 406x406 and the resized image is converted into an array that has double precision. The array is then sent to the Gabor Filter and then to the Complex Cell function for further processing. Figure 3 shows the algorithm used for this stage of the process.

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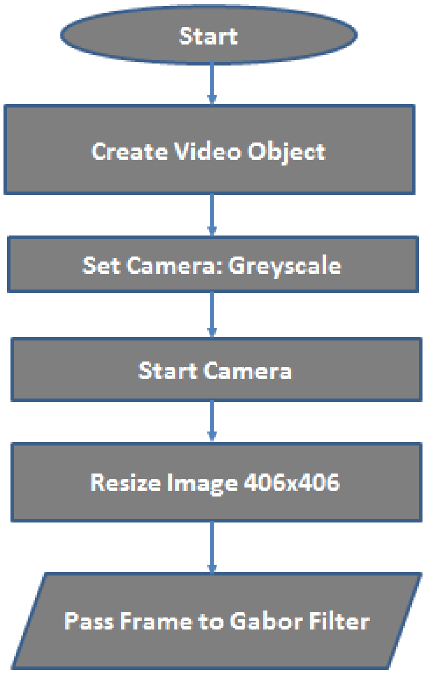

Figure 3. Webcam Algorithm

B. Gabor Filter Function: Ganglion Cell and Simple Cell

We used the Gabor Filter function in the model since “Gabor Filters have the properties of spatial localization, orientation selectivity, and spatial frequency selectivity”. Basically, “depending on the parameter used, this filter made it possible to better characterize the information about structure of directional angles and width of ridges” [5]. In our model, the Gabor Filter was a combination of Ganglion Cell and Simple Cell functions to detect edges of objects with specific orientations. The input array from the webcam function is resized to 406x406, and then the Gabor Filter function creates two filter-sized arrays of 7x7 and 9x9. These two filter-sized arrays pass four different outputs for each orientation to the Complex Cell function.

Figure 4 shows the Gabor Filter Algorithm of our program. As mentioned before, the input array with a size of 406x406 is obtained from the webcam function. Then, the Gabor filter function creates two filters with different sizes and kernel values. These two filters are responsible to "filter" the input array and output eight different new arrays (406x406 each) from four different orientations which are 0, 45, 90 and 135 degrees, that is, two output arrays per orientation (refer to Figure 4). Since the Gabor filter detects the edges of the object and also the edges of the frame, a new array is created by crossing out the boundary of the original array, then, the eight final arrays are size 400x400 (refer to Figure 5a and Figure 5b).

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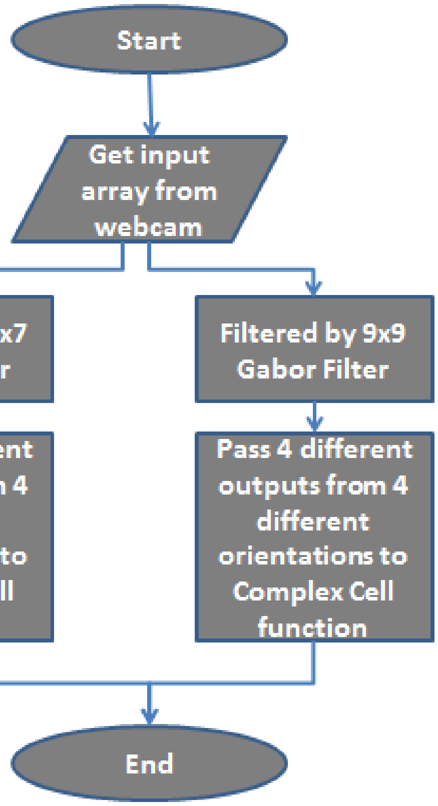

Figure 4. Gabor Filter Algorithm

255	255	255	255	255	255	255
255	125	115	12	11	14	255
255	10	124	122	8	9	255
255	9	17	127	130	4	255
255	5	6	14	119	124	255
255	8	9	15	16	122	255
255	255	255	255	255	255	255

(a)

125	115	12	11	14
10	124	122	8	9
9	17	127	130	4
5	6	14	119	124
8	9	15	16	122

(b)

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Figure 5: (a) Sample Array and (b) New Array after crossing out the boundary

The main concept of the Gabor Filter Function is the Convolution Process. The convolution process performs a weighted average of all the pixels in the specified neighborhood. Basically, the final pixel after the convolution is equal to the sum of the products between the values of each nearby pixel with the kernel values (weights). Therefore, each pixel in the final image will generally contain, at least, a small part of all other pixels locally surrounding it. The color of each pixel in the image is either added to (blurred) or subtracted from (sharpen/edge detection) the colors of all its nearby neighbors, as defined by the kernel used and shown in Figure 6.

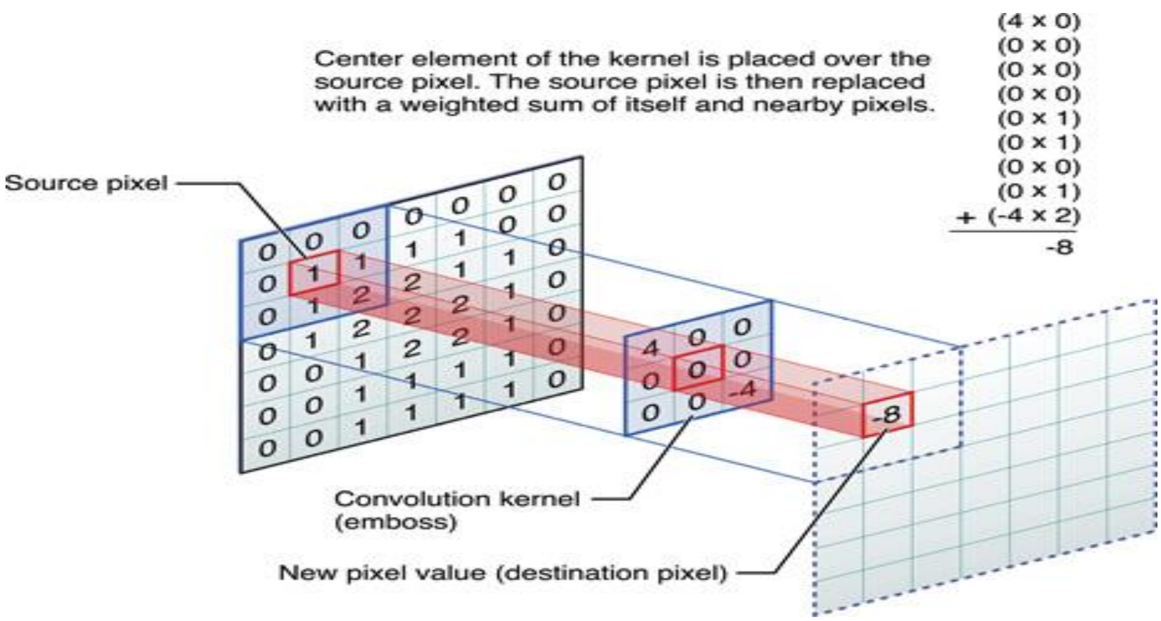

Figure 6. Convolution Process and Kernel Values[3]

C. Complex Cell Function

Complex Cells tend "to show some tolerance to shift and size and have larger receptive fields, which are twice as large as Simple Cells. Complex Cells respond to oriented bars or edges anywhere within their receptive field and are in general more broadly tuned to spatial frequency than Simple Cells (scale invariance)" [8]. In our model, the two filter-sized arrays (which are 7x7 and 9x9) from the Gabor Filter are resized to 8x8. The Complex Cell function takes the maximum from the two arrays with the same orientations. If the values in the array are greater than the threshold, the values are equal to 255 and if the values in the array are less than the threshold, the values are equal to 0. For the output results the 255 is white and 0 is black.

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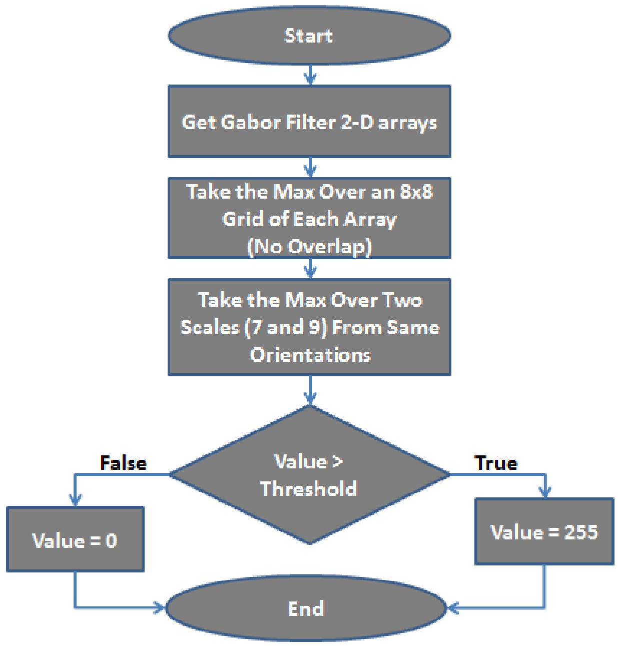

Figure 7. Complex Cell Algorithm

As shown in Figure 7, the inputs to the complex cell are the output arrays (400x400) from the Gabor filter function. The complex cell function calculates the max pooling [7] for these arrays and gets four different new arrays (size 50x50). Afterwards, a threshold value is used for comparison; if the values in the new arrays are greater than the threshold value the values are set to 255. Otherwise, the values are set to 0. At the end, the arrays are shown as an image plot for better understanding of the results.

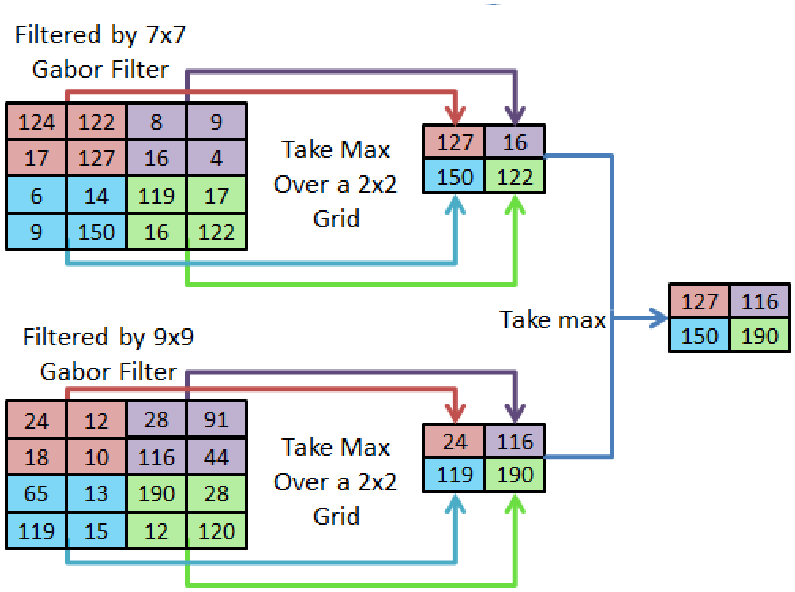

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Figure 8. Max Pooling Example

The main concept of the complex cell function is the max pooling. Basically max pooling is a process where the maximum over an 8x8 grid array is taken for each array, and then the maximum over two scales (7 and 9) from same orientations is taken as shown in Figure 8.

IV. Results and Analysis

For the extensive testing of the program, we first used a fixed image stored in the computer. One of the fixed images used was Lenna Gray's picture (Figure 9) which is frequently used to test image processing algorithms. Once the fixed image was processed, the image plot of the results showed that 0, 45, 90, and 135 degrees for orientation detection were sufficient to recognize images with a higher degree of complexity. Figure 10 shows the image plot result for Lenna Gray's picture.

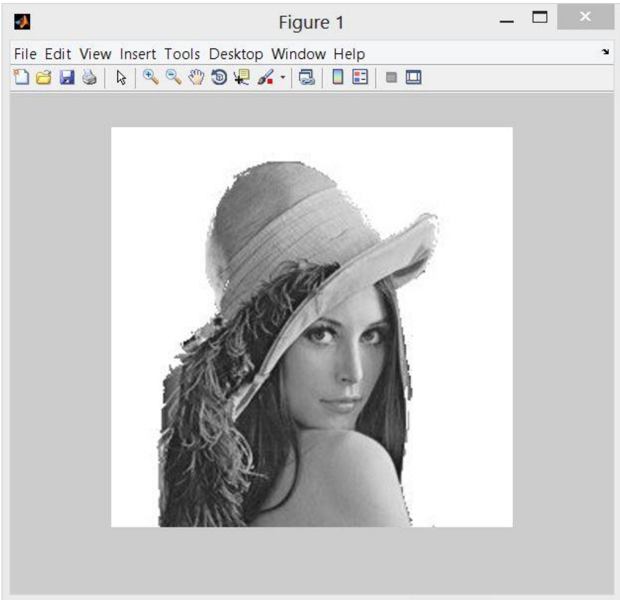

Figure 9. Lenna Gray image

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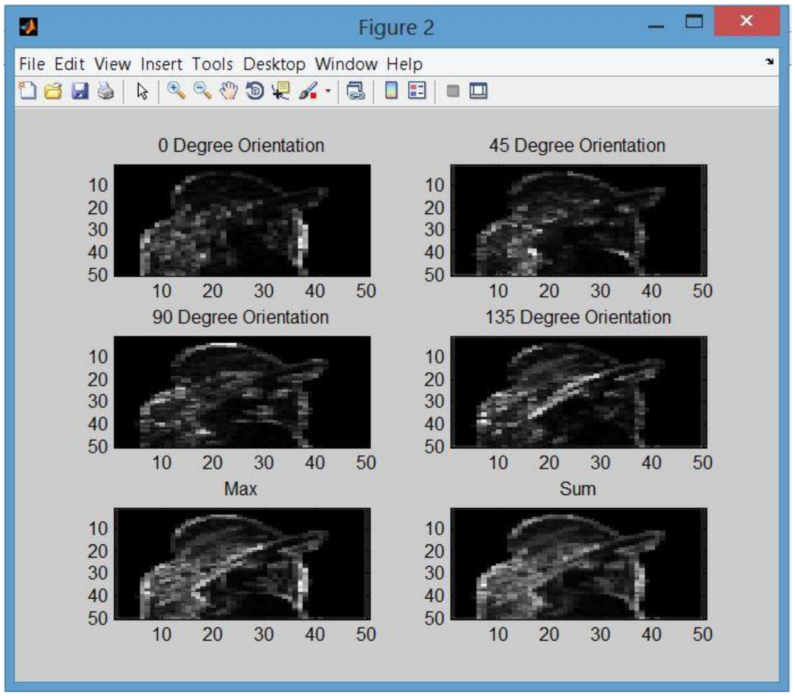

Figure 10. Image Plot Lenna Gray's picture for different orientations

In addition we were able to use the webcam to capture and process live video stream. To test the live stream video results, we used three different shapes, a square, right triangle, and circle, and as we rotated the objects, and the program was able to detect the edges for 0, 45, 90, and 135 degrees. Figures 11, 12, 13, and 14 show the screenshots of the live video stream results including the angles detected as well as the maximum and sum. The first row has the results for 0 and 45 degrees, the second row has the results for 90 and 135 degrees, and the last row has the max and sum of all the edges.

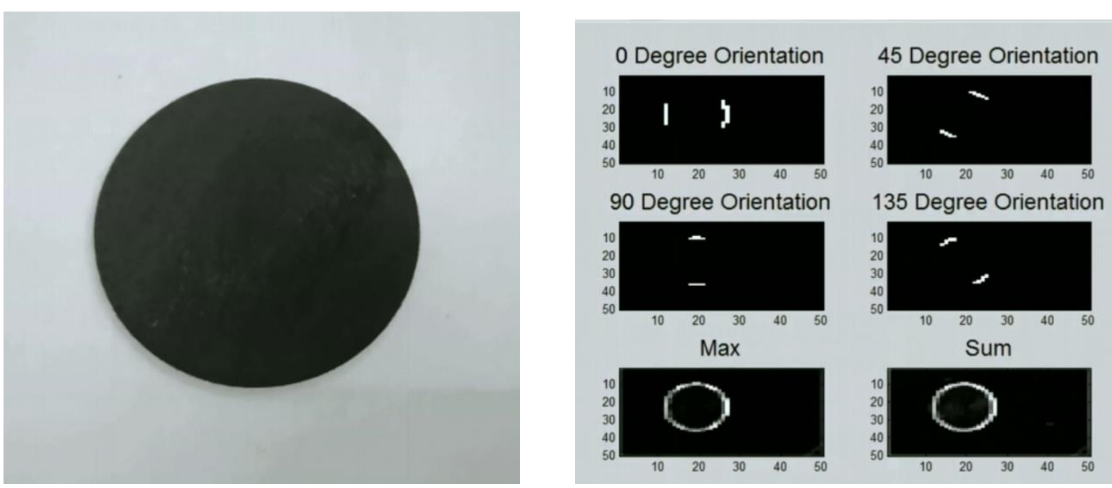

Figure 11. Circle recognition in a live video stream

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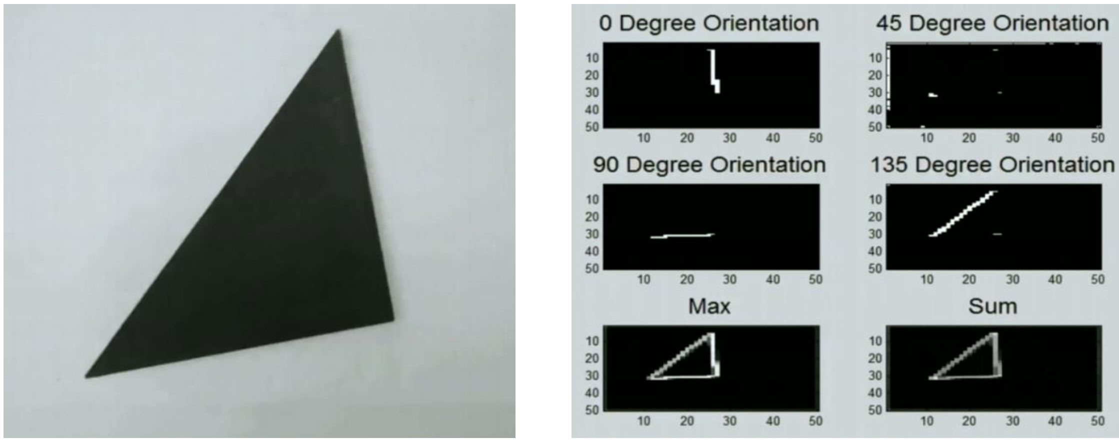

Figure 12. Triangle recognition in a live video steam

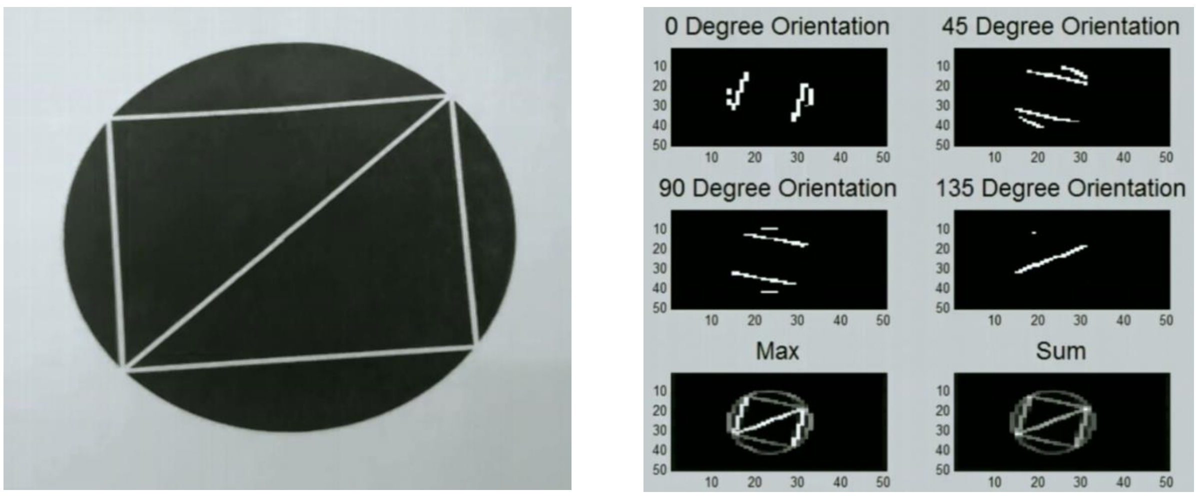

Figure 13. multiple edges recognition in live video stream

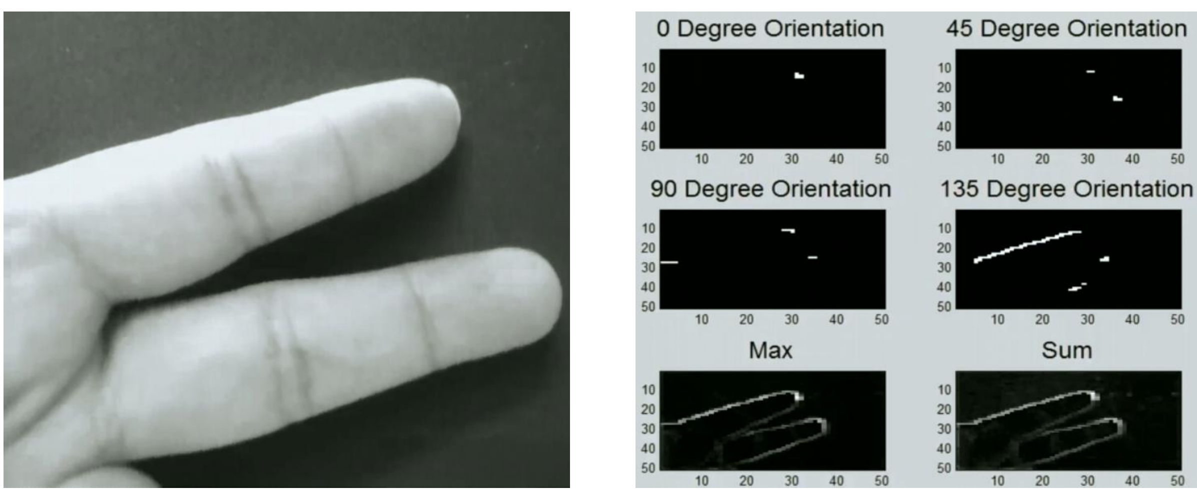

Figure 14. Fingers recognition in a live video stream

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Initial results showed that the detection of edges with specific orientations was mostly accurate. However, we noticed that while rotating, for instance, the square image, there were spots where one edge was missing in the max and sum outputs. Based on our latest tests we concluded that it was an issue related to the factor used for the threshold. Originally we were using a threshold factor of 0.7 to remove more noise in the background. Hence, reducing the threshold factor to 0.5 increased the output quality and eliminated the missing edge issue that the program presented before. Table 1 shows the Run-Time and Frame-Rate for each function running from computers with different capabilities. We concluded that the performance of the program is affected by the size of the input image, CPU frequency, and RAM capacity.

Table 1. Run-Time and Frame-Rate for each function of the program running on computers with different capabilities

Function	Processor Intel® Core™ i5 CPU 750@ 2.67GHz RAM 4.00GB		Processor Intel® Core™ i7-3630QM CPU @ 2.40GHz RAM 12.00GB	
	Elapsed time sec/frame	Frame Rate frames/sec	Elapsed time sec/frame	Frame Rate frames/sec
Webcam	0.005056	197.7848	0.014442	69.24249
Gabor Filter	0.053685	18.62718	0.06233	16.04364
Complex Cell	0.014453	69.18979	0.012744	78.4683
Threshold	0.398003	2.512544	0.388765	2.572248
Output Data	0.055967	17.86767	0.072881	13.721
Total	0.527164	1.896943	0.5381642	1.858168

V. Student Surveys

Table 2, 3, and 4 summarize the results of post-program student surveys designed to measure perception of over-all impact of the research internship program on student participants in the past two years. Results show that the research internship program was successful in its achieving its goals of helping students prepare for transfer, solidify their choice of major, increase their confidence in applying for other internships, and enhance their interest in pursuing graduate degrees. Overall, students were satisfied with the program, and would recommend it to a friend. The internship program was successful in achieving its goals of developing students' skills needed for academic success.

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Table 2. As a result of your participation in the program, how much did you learn about each of the following? Response Scale: 1 – Nothing; 2 – A little; 3 – Some; 4 – Quite a bit; 5 – A lot.

Activity	2013	2014
Performing research	4.94	4.31
Designing/performing an experiment	4.88	4.50
Creating a work plan	4.81	4.69
Working as a part of a team	4.81	4.56
Writing a technical report	4.63	4.50
Creating a poster presentation	4.69	4.63
Making an oral presentation	4.81	4.50

Table 3. Tell us how much you agree with each of the following statements. Response Scale: 1 – Strongly Disagree; 2 – Disagree; 3 – Neutral; 4 – Agree; 5 – Strongly Agree.

Activity	2013	2014
The internship program was useful.	4.94	4.56
I believe that I have the academic background and skills needed for the project.	4.63	4.44
The program has helped me prepare for transfer.	4.88	4.19
The program has helped me solidify my choice of major.	4.81	4.19
The program has helped me solidify my choice of transfer university.	3.75	3.56
As a result of the program, I am more likely to consider graduate school.	4.06	3.81
As a result of the program, I am more likely to apply for other internships.	4.94	4.75
As a result of the program, I am more likely to consider SFSU as my transfer institutions, or recommend it to others.	3.75	3.13
I am satisfied with the NASA CIPAIR Internship Program.	4.81	3.75
I would recommend this internship program to a friend.	4.88	4.56

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Table 4. Tell us how much you agree with each of the following statements. Response Scale: 1 – Strongly Disagree; 2 – Disagree; 3 – Neutral; 4 – Agree; 5 – Strongly Agree.

	Pre	Post	Difference
I have a clear career path.	4.38	4.38	0.00
I have skill in interpreting results.	4.38	4.38	0.00
I have tolerance for obstacles faced in the research process.	4.44	4.56	0.13
I am ready for more demanding research.	4.25	4.38	0.13
I understand how knowledge is constructed.	4.19	4.69	0.50
I understand the research process in my field.	3.31	4.31	1.00
I have the ability to integrate theory and practice.	4.06	4.25	0.19
I understand how scientists work on real problems.	4.00	4.06	0.06
I understand that scientific assertions require supporting evidence.	4.69	4.56	-0.13
I have the ability to analyze data and other information.	4.56	4.56	0.00
I understand science.	4.44	4.44	0.00
I have learned about ethical conduct in my field.	4.25	4.44	0.19
I have learned laboratory techniques.	4.00	4.13	0.13
I have an ability to read and understand primary literature.	4.50	4.38	-0.13
I have skill in how to give an effective oral presentation.	4.19	4.44	0.25
I have skill in science writing.	3.94	4.13	0.19
I have self-confidence.	4.50	4.63	0.13
I understand how scientists think.	3.94	4.31	0.37
I have the ability to work independently.	4.50	4.75	0.25
I am part of a learning community.	4.44	4.81	0.38
I have a clear understanding of career opportunities in science.	4.31	4.63	0.31

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VI. Conclusion

We have successfully modeled a brain-inspired neural network for edge and orientation recognition using MATLAB (a high-level technical computing language). We successfully demonstrated the validity of the model on live video stream as well as fixed images. The model was able to detect 0, 45, 90, and 135 degrees, while running functions representing different cells of the brain making it a true brain-inspired model. After testing, we determined that the greatest challenge for this prototype is the run-time. Nevertheless, we have created a framework for further expansion and research where hardware implementation might solve the actual run-time issues. Hence, the use of this prototype with a self-trained artificial neural network for object recognition will lead to a further stage of the project. With this foundation, future researchers can include new visual processing tasks such as depth, color, shapes, and much more. On the educational side, this presented summer research internship program has shown its effectiveness in not only transferring technical knowledge and experience to undergraduate students, but also offering them an opportunity to discover their passion and career pathways.

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From One to Many: Building an Effective Teaching Team for Capstone Courses

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Abstract

This paper describes a shift from a solo instructor paradigm to a two-instructor team-teaching paradigm and then to a multi-instructor teaching team paradigm for senior-level capstone courses at Embry-Riddle Aeronautical University, Prescott campus (ERAU/Prescott). Specifically, this paper recounts how various instructors and advisors joined a solo engineering instructor to first provide instruction in technical communication (two-instructor team-teaching) and then to provide supplemental instruction in the design, analysis, manufacture, and testing of aircraft and unmanned aerial systems (multi-instructor teaching team) and how, over time, these teaching teams are becoming the norm for all capstone courses at this university. Many instructors attempt to improve their engineering classrooms by enriching their teaching materials, teaching methods, or student learning strategy; however, these improvements tend to maintain the standard classroom practice of assigning one instructor to one class. While a single instructor may be sufficient for traditional lower division courses, this paper argues that multiple instructors with multiple sets of expertise may provide more effective instruction in helping students achieve the many and varied outcomes required for engineering capstone courses. Moreover, non-traditional instructors and advisors (e.g., members of the local business community, writing teachers, pilots retired from military service) who make their expertise available to capstone students when they join the teaching team add value to the capstone experience by demonstrating multi-disciplinary approaches to design and testing. Finally, by teaching in multidisciplinary teams, the capstone instructors may model successful team behavior to students who are themselves working in design teams. By allowing students to observe successful team behavior, the teaching team prepares students to engage in successful team behavior themselves, as per ABET Outcome 3d.

This paper traces the development of engineering capstone courses at ERAU/Prescott, from the solo instructor model through the team-teaching model to the current teaching team model, describes the evolution of one specific capstone course (Aircraft Detail Design) and as a justification of the need for teaching teams, identifies the diverse professional backgrounds of some members that have joined teaching teams at ERAU/Prescott, outlines several benefits of the teaching team model, notes challenges that have arisen in integrating instructors and advisors with diverse backgrounds into the teaching team, and suggests ways that solo instructors might begin to develop their own teaching teams.

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Context

ERAU/Prescott is a 4-year university located in Northern Arizona with an enrollment of approximately 2000 undergraduate students. The two most popular engineering degree programs are Aerospace Engineering (AE) and Mechanical Engineering (ME). Within the AE/ME curriculum, there is a strong emphasis on hands-on application and conceptual design projects to prepare students for senior capstone design courses.

Students majoring in AE or ME must choose one design track: Aircraft or Spacecraft for AE's and Propulsion, Robotics or Energy for ME's. Each track culminates in a sequence of two senior design courses: Preliminary Design and Detail Design.

In each of the Preliminary Design courses, students work in teams to perform conceptual and preliminary design of an overall system. In the Detail Design courses, each team typically selects a set of subsystems from their preliminary design and performs physical testing (e.g., wind tunnel testing, structural testing, flight testing). These test results are then compared to computer-based simulations and are documented in written reports and presented by each team at a formal briefing at the end of the semester. This formal briefing is open to the university and is scored by a panel consisting of faculty members and guests from industry. Throughout the two-semester design process, students receive instruction from a technical writing professor from the Department of Humanities/Communications (i.e., COM professor) in how to document and present their work and how to effectively work in teams[1]. This instructor is embedded in the classroom. This pairing of two professors from different disciplines who deliver the content of a single class in a collaborative manner is called team-teaching[1, 2].

The team-teaching concept in capstone courses has been in place in ERAU/Prescott's engineering program for over a decade[3]. Recently, however, as more complex projects requiring a wider knowledge base have been pursued, this collaborative teaching arrangement has been expanded to better equip the students with the skills required to effectively complete their designs. The following section will provide an overview of the history of team-teaching at ERAU/Prescott and its evolution within these senior capstone courses from two-instructor team-teaching to multi-instructor teaching teams.

Team-teaching and Teaching Teams in Senior Capstone Courses

This section defines team-teaching and describes how team-teaching has evolved along with the senior design capstone courses at ERAU/Prescott from a pair of teachers to multi-disciplinary, multi-instructor teaching teams. Team-teaching is typically defined as a collaborative teaching effort in which two faculty members deliver the content of a single course, sharing the burden of course preparation, lecture, in-class tasks, and assessment [1, 2]. One purpose of team-teaching is to supplement gaps in student education (typically gaps in math or communication or ethics or

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leadership skills); this supplementation is accomplished not by tutoring or by external labs but by integrating the supplemental instruction directly into a specific course content. By deeply embedding this supplementary education, the instructors provide students with contextualized, disciplinary-specific instruction in the skill in question (e.g., instruction in various documentation strategies used in the aerospace engineering industry, instruction in ethical business practices)[4, 5, 6].

Before 2003, senior design capstone courses at ERAU, Prescott were taught by solo instructors who were responsible for all course content, delivery, and assessment. In 2003, the AE/ME faculty began team-teaching with COM professors in the capstone courses[3]. The instructors adopted this non-traditional approach in order to address students' weaknesses in communication, specifically to refine their skills in giving formal presentations and in writing technical documents (e.g., test plans and test reports) so as to better meet ABET Outcome 3g. This team-teaching initiative was implemented in a single section of capstone; over several years the initiative proved to be successful as student presentations and documentation demonstrated measurable improvement as assessed at the beginning and the end of each term. Therefore, team-teaching was implemented throughout the capstone courses, so that by 2009 all sections of senior design capstone were team-taught by pairs of AE/ME and COM faculty[2].

Embedding a COM instructor in each AE/ME capstone course provided students with an in-class resource regarding communication or teamwork skills. Communication instruction was tailored to the specific capstone project and students' immediate needs, so this instruction was contextualized and of immediate practical use. For example, students working on industry-sponsored projects received instruction on holding business meetings using distance technology[7].

Once team-teaching was implemented, the faculty found that it had some unexpected benefits. Significantly, because the COM instructors relieved the AE/ME faculty of the time-consuming task of teaching communication in the capstone classes, the AE/ME faculty gained sufficient time to introduce more sophisticated and complex technical material into the capstone courses.

For example, before team-teaching was introduced in 2003, students created "paper designs" that were fabricated as scale models and wind-tunnel tested. In 2003, the AE faculty member who introduced team-teaching was also able to introduce structural testing, and students designed, analyzed, manufactured, and structurally tested a scaled test article representative of an exposed wing section. Most recently, students have begun to design full-scale unmanned aerial systems (UAS) that undergo wind-tunnel testing, structural testing, and eventual flight-testing. (A richer description of the evolution of capstone projects is provided in the following section.)

Because of the increasing technical complexity of student design projects, students often need to acquire knowledge and skill sets that are outside the immediate expertise of the AE/ME and COM faculty (e.g., techniques for fabricating a full-scale wing for a UAS from composite

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material, procedures for purchasing material for manufacture). Rather than reduce the technical complexity of these capstone projects, the faculty chose another path – they invited other experts to form a multi-disciplinary, multi-instructor teaching team to support the students' capstone projects. Faculty, staff, and members of the local community reacted positively to these invitations to collaborate and agreed to join these teaching teams. Most recently, in the Fall 2014 Aircraft Detail Design course, the teaching team consisted of seven collaborators: the AE instructor, the COM instructor, the campus' Machine Shop Manager, the College's Lab Manager, the College's Administrative Assistant/Budget Manager, a retired US Army UAS pilot, and a radio controlled (RC) aircraft expert.

While standard team-teaching arrangements are typically comprised of a single pair of faculty[1], teaching teams are comprised of three or more instructors. These instructors include both university faculty and non-traditional instructors (e.g., staff members, technicians, retired engineers living in the local community, and members of the local RC airplane club), all of whom serve as teachers, advisors, informants, and mentors. The transition from team-teachers to teaching teams has proven to be of significant value to the capstone students (and to the AE/ME and COM faculty), and in the past few semesters, multi-disciplinary teaching teams have been formed by other capstone instructors at ERAU, Prescott. The strength of this type of multi-disciplinary, multi-instructor teaching team is the variety of expertise made available to student design teams; by accessing the expertise of their various instructors and mentors, students have been successfully tackling design projects of increasing complexity, as will be discussed in the next section.

Aircraft Detail Design Project History

The authors have both served as instructors in the Aircraft Detail Design course over the past 12 years. When first assuming their instructional roles for the course, the authors were focused on adding application of theory through physical testing and communication skills to the existing course content. The physical testing involved the design, build and structural testing of scaled down aircraft components (e.g., wing or tail sections), in addition to the wind tunnel testing that was already an integral part of the course. The communication instruction involved the addition of presentation and documentation instruction by a COM instructor who was embedded in the AE classroom, as has been described in previous sections.

The student projects for this course were initially inherited from an Aircraft Preliminary Design course taught by a different instructor. The projects ranged from first-stage-to-orbit vehicles to small propeller-driven personal aircraft. **Figure 1** and **Figure 2** below show examples of the wind tunnel models developed for these projects.

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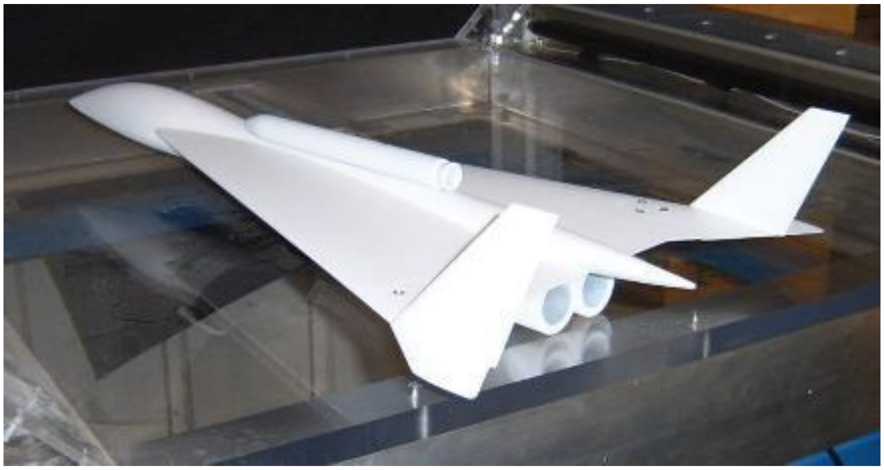

Figure 1: First-Stage-to-Orbit Vehicle Wind Tunnel Model

Figure 2: Personal Use Vehicle Wind Tunnel Model

Both of the models shown in the preceding figures were fabricated using a Rapid Prototyping (RP) system, which required coordination between the design teams and RP Lab Technicians.

The projects resulting in designs such as that depicted in **Figure 2** would be further evaluated through scaled component structural testing, as shown in **Figure 3** below.

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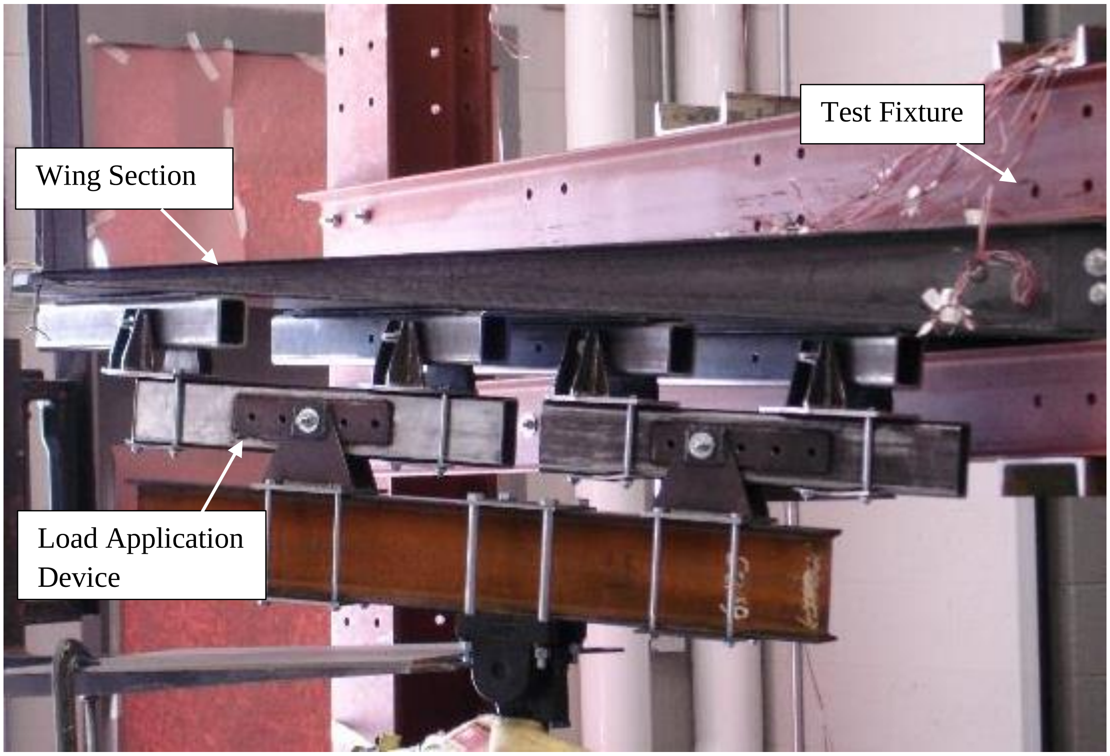

Figure 3: Structural Test of First-Stage-to-Orbit Scaled Wing Section

The previous figure shows a distributed load being applied to a carbon composite model of a scaled wing section of the aircraft. The manufacture of the test article required coordination with the ERAU/Prescott Lab Manager who was familiar with composite material manufacturing methods, and the ERAU/Prescott Machine Shop Manager who guided students through the fabrication of the steel load application device and the steel fixture which supported the test article throughout the loading process.

The design depicted in **Figure 3** is representative of a transition which occurred in 2006, when ‘design, build, break’ component structural tests were supplemented with ‘design, build, fly’ testing of scaled propeller driven aircraft. The scaled aircraft designs were typically derived from manned aircraft missions, but allowed students to both structurally test their designs and develop a flight test article suitable for testing using RC components. An image of a sample flight test article is shown in **Figure 4** below.

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Figure 4: Flight Test Article and Design Team

The previous figure shows a 1:3-scale personal use aircraft design along with the students who designed it. The photo was taken at a local RC airfield whose members include former aerospace engineers and members with vast experience in building and flying RC aircraft. These flight test articles were fabricated using a combination of composite and aluminum structure which, again, required the assistance of the Lab Manager and Machine Shop Manager at ERAU/Prescott.

Within the past year, the course has evolved to be aimed solely at small unmanned air system (SUAS) design. The authors now team-teach both Aircraft Preliminary Design and the subsequent Aircraft Detail Design course, following their students through the entire senior capstone design process. In Preliminary Design, the student design teams start with a request for proposal (RFP) written in response to a contemporary and socially relevant issue, and develop a systems design involving payload and communication integration in addition to the aircraft requirements addressed in previous years. This added content has resulted in the need for assistance from Electrical Engineering/Computer Engineering (EE/CE) faculty; these faculty and other staff and advisors have joined with the course instructors to form a collaborative, multidisciplinary teaching team willing to work with students throughout the senior capstone

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design process. A more detailed explanation of the requirements for this new course sequence in terms of teaching teams is provided in the following section.

SUAS Project Requirements and Teaching Teams

Recently, the increasingly complex requirements for Aircraft Preliminary Design were such that the course instructors decided to add new members to the teaching team to help students meet these new requirements. In addition to the EE/CE faculty previously mentioned, SUAS and RC aircraft experts were incorporated into the team as discussed in the following paragraphs.

A former US Army UAS pilot who joined ERAU as an adjunct instructor in our College of Aviation became a key member of the team. This UAS pilot provided the course instructor with guidance in developing RFP's that were relevant to contemporary issues, which allowed the course to better address ABET Outcome 3j. He also worked directly with students as they formulated their designs, ensuring that the teams' self-imposed design constraints were appropriate to their project. His experience also provided students with an understanding of how their designs would potentially provide a positive impact on society, thereby reinforcing the attainment of ABET Outcome 3h. His experience was invaluable as a panel member during design reviews, where we was able to provide valuable critiques and suggestions which led to both improved system designs and more expedient solutions to design problems. His most critical contribution came during flight test of the proof of concept flight test articles when he successfully piloted the aircraft, providing the students (and instructors) with the thrill of seeing their concepts take flight.

The addition of RC aircraft experts to the team was advantageous for several reasons. Since the aircraft could not be flight tested as autonomous UAS under FAA regulations, they were fitted with RC aircraft components and flown as glorified RC aircraft (or proof of concept flight test articles). The RC aircraft pilots used their experience to provide many tips and tricks they had learned over the years in terms of component installation and system check-out. They also provided guidance when components did not work as expected, lending tools and even spare components to the students to help ensure a successful flight test. The primary teaching team member from this group of RC aircraft experts is also a retired Lockheed Skunk Works engineer, who attended the design reviews and offered advice from an engineering perspective. Perhaps most importantly, the RC aircraft experts provided access to a newly refurbished airfield with an 800 ft. paved runway (partially shown in **Figure 4** above) and ample work area.

As this section shows, teaching teams may be comprised of faculty and non-faculty members collaborating for the students' educational benefit. The next section will illustrate some of the professional expertise and services that non-faculty members can bring to teaching teams.

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Multidisciplinary Backgrounds of Non-faculty Teaching Team Members

The teaching team model has been found to be successful at providing capstone design students with timely supplemental instruction, so much so that the formation of teaching teams is becoming the norm for all capstone courses at ERAU/Prescott. However, each capstone course has varied content and outcomes, and so the expertise and backgrounds of the team members are also varied. Some team members are faculty; for example, as discussed in the previous section, an EE/CE instructor was a much needed addition to the Aircraft Preliminary Design teaching team. Many other team members, however, are not faculty; for example, in Spacecraft Detail Design, the campus' Chief of Safety and Security joined the teaching team to guide students in the proper safety protocols required before a rocket engine could be ignition tested on campus. In this section, the professional backgrounds of some of the non-faculty members of these multidisciplinary teaching teams are described and the contributions these members have made to their students' projects are identified.

Expert Bronzesmith: The master smith of the local bronzeworks teamed with the Propulsion Detail Design course to provide instruction on how bronze and other metals are cast. Students toured the bronzeworks, were given instruction on hot pouring techniques, and eventually purchased heat shields, a forge, and other equipment that allowed them to cast a propeller that they designed. The bronzesmith was invited to the casting where he served as a safety adviser; he also attended the end-of-term public presentation and helped assess the team's project.

Retired Program Manager: A program manager who was retired from Raytheon and was living in the Prescott area teamed with Spacecraft Preliminary Design and with Spacecraft Detail Design. He sat as a panelist for several design reviews over the course of the year, asking cutting questions and providing expert feedback that helped students refine their design and refine their presentation skills.

Flight Test Engineers: Several flight test engineers from Edwards Flight Test Center teamed with Propulsion Detail Design as well as with Aircraft Detail Design to provide lectures on flight test plans and procedures. These engineers provided supplementary handouts and slide shows to guide students through the testing process as well as the documentation process. They also served as panelists at end-of-term public presentations and helped assess the team's project.

Captain, USAF: An officer with the US Air Force teamed with Spacecraft Preliminary Design to provide a lecture on budget management and labor hours accounting, particularly in regards to government contracts. He also provided technical feedback during some informal presentations, and attended the more formal end-of-term public presentation to assess the team's progress.

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As this brief sample shows, non-faculty members of teaching teams at ERAU/Prescott have rather diverse backgrounds that allow them to provide specialized knowledge and skill sets that enrich students' learning experiences – knowledge and skills sets that the original two team-teachers could not provide. The next section summarizes the benefits and challenges of forming an effective multi-disciplinary teaching team.

Benefits and Challenges of Teaching Teams

Some of the tangible benefits of inviting faculty, staff, and community members to join a senior design teaching team are obvious, namely that students have ready access to professionals with expertise that differs from that of their course instructors. These areas of expertise range from the design of navigation and propulsion systems to the sanctioned procedures for purchasing materials for fabrication to the security protocols required for engine tests to the pre-flight procedures for the flight test of a prototype SUAS.

What may be less obvious is that by working in multidisciplinary teaching teams, the members illustrate collaboration, negotiation, mediation, communication, and other "soft" skills required of any successful design team. In this way, the instructors can model healthy and productive team behavior to their students who can then adopt these same behaviors in their own design teams. Rather than merely telling students how to engage in good team skills, teaching teams can actually model these very skills. As such, teaching teams help students to achieve ABET Outcome 3d.

Aside from these benefits, forming and managing a teaching team can also pose challenges; two key challenges experienced by the authors were managing student requests for assistance and finding replacement team members.

<u>Managing Student Requests</u>: Once students realize they have access to sources of expertise other than their course instructors, they sometimes will swamp a team member with multiple requests for meetings, advice, and feedback. Some team members (e.g., retired aerospace engineers) welcome as much student contact as possible while others (e.g., faculty from other departments) report feeling overwhelmed by multiple students who request multiple meetings.

To alleviate this "swamping" syndrome, the authors recommend establishing a protocol for students to follow. First, whether they have a technical, budgetary, or communication problem, students are to work through as much of the problem by themselves as possible. Second, students are to document their work to date and have it presentable for quick review. These strategies prevent students from showing up empty-handed to meetings and sometimes alleviate the need for a meeting altogether. Third, students are to meet with other members of their design team first to share their work and, if they need a meeting with a member of the teaching team, they are

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to schedule a single meeting that all students can attend. This strategy avoids the member of the teaching team being peppered by numerous queries regarding the same problem and increases efficiency. Encouraging students to follow these strategies has reduced the number of reports of "swamping" and has helped students to refine their professional behavior.

The authors also recommend an exchange of services, if tenable, so that faculty work on each other's teaching teams. In this way, both faculty members are giving and receiving support, and students in both classes benefit from the addition of expertise to their class environment.

Replacing Team Members: Because many of the members of the teaching teams described in this paper are not full-time faculty at ERAU/Prescott, they tend to be able to commit to only a few semesters at a time due to travel or other obligations. Thus, there is some turnover of team members from semester to semester, and finding new team members with the pertinent skillsets can be challenging.

To minimize the disruption that can occur when a member leaves the teaching team, the authors have begun to form relationships with organizations that can provide a 'pool' of potential team members. Most notably, the lead author formed a relationship with the local RC airplane club. As previously noted, the club membership includes numerous retired aerospace engineers, including a Skunk Works retiree, and expert SUAS and RC pilots, and the club owns its own airfield just north of Prescott. Because of this ongoing relationship, students have continued access to aerospace experts and to an airfield for testing, and the club has continued opportunity to advertise their club on campus and thus gain new club members.

Neither of the challenges mentioned above is insurmountable. The primary strategy for overcoming these challenges is clear communication between the team members regarding each member's obligations to the students and to the teaching team, including a clear statement of how long the member will participate in the teaching team.

The final section of this paper provides suggestions for a solo instructor who wishes to create a teaching team for their own engineering class.

Conclusions and Recommendations

The formation of a multi-disciplinary, multi-instructor teaching team can provide engineering students with supplementary instruction and access to advice and expertise that they otherwise would not have if their capstone course were only taught by one or two faculty members. A teaching team can also model effective team behavior so that students can practice similar behavior when interacting with their own design team. In this way, the presence of teaching teams in engineering capstone courses help students to meet ABET Outcome 3d.

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The following suggestions are based on the experiences the authors have had in forming their own productive teaching team and are offered to those solo instructors who wish to follow suit:

1. Identify the most critical "gaps" in both the instructor's and the students' skill sets.

2. Identify an individual or organization who can fill that gap. Remember to consider faculty in different departments as well as to non-faculty members: staff members, alumni, business partners, and community members.

3. Make a list of specific responsibilities for the potential team member: Will they give occasional lectures? Be available for student meetings outside of class? Attend presentations and events such as structural tests? Assess projects?

4. Decide how much contact with students the potential team member will have: Will they attend every class, every day? Will they attend class occasionally? Will they be available throughout the semester or the academic year as the student need? Will they only be part of the project during a limited time period, for a specific function?

5. Negotiate the above with the team member, including how students will contact the team member.

6. Negotiate what, if anything, the team member would like in exchange for this voluntary service (e.g., an opportunity to advertise their organization on campus, access to lab equipment, an exchange of teaching services).

7. Introduce the team member to the students and the rest of the teaching team as early as is feasible; include them when possible on all teaching team communications and, if desired, on all student communications.

8. Provide strategies for the students to most efficiently and effectively request and receive expert guidance from their teaching team.

9. Meet with the team member periodically to provide feedback on their contribution to project and to get feedback from them as well.

10. Use networking strategies to create a pool of replacement team members.

By following these suggestions, teaching teams may be formed which provide rich benefits to both instructors and students.

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Netshape
Metal Casting, Rapid Prototyping and CAD/CAM
30 Minutes Art to Part

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Abstract

This paper will describe the evolution and transformation of a traditional foundry practices lab into a Netshape lab which maintains the hands-on metal casting activities but integrates them with Additive Manufacturing (AM) and Computer Numerical Control (CNC) for the rapid production of patterns, molds, and castings. This is a one unit freshman level course with no prerequisites. It is a three-hour, one unit course that meets for 10 weeks and is taught in a lecture/activity format. The mission of the course is to teach engineering students about the wide array of processes that comprise the metal casting industry. This is done through a combination of traditional lecture, interactive computer tutorials/ case studies, traditional foundry lab experiences and the use of CAD/CAM systems to produce CNC milled patterns and AM produced patterns and molds.

Our engineering programs are hands-on. We firmly believe that the educational experiences are greatly enhanced by projects and the making of things. In the evolution of the course it became apparent that the need for careful planning to avoid a bottleneck that could occur in the production of foundry tooling had to be overcome. The desire was to be able to enable the students to quickly make the design, the tool, the mold and the casting without getting bogged down in a long process that took a great deal of knowledge to be successful. We are introducing them to these processes and not training them to be experts. Therefore we had to come up with processes where the students, could be successful in producing a part in a very short time frame, learn a great deal and have fun. The paper will describe the course objectives, methodologies, the equipment and systems used.

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Introduction

How to turn a staid foundry practices course into a NetShape course.

In the late 80's / early 90's of the last millennium I was assigned to teach our Foundry Engineering course for the Industrial Engineering Department. Up to this point I had only been teaching automation and computer science courses and knew nothing about the industry. To learn about it I began a relationship with the industry through it's professional societies and companies. I became, and still am, quite enamored with it's wide range of processes and methods. Molten metal is cool. What was not cool was the existing course content. It was a "stuck in the mud", dry course that did give an insight into the processes but the labs were un-engaging. Probably the worst experiment that we had was one of sand control where a specimen of greensand was weighed in the wet condition, dried with an industrial hair blower and then weighed in the dry condition producing data to be used to calculate the moisture content of the sample. It was as exciting as watching "paint dry". Additionally the objects that were cast consisted of the standard old patterns of a large replica on an "Indian Head" coin, etc. Whatever we had is what you were stuck with. The course was mired in the past and doomed for elimination. In order to survive, it need to morph into something more. Something that could still give our students an understanding of how things are made but additionally give them tools to make things; to "Learn by Doing".

In computer science you can easily "make things" by writing new code. In foundry it became clear that there was something I call "The Tooling Bottleneck" that greatly hindered making new stuff. The Tooling Bottleneck can be explained as the situation where you basically have to make your production tooling in order to get a prototype casting. A functional prototype is one that is made in the desired material via the desired process. A conceptual prototype made out of plastic just doesn't cut it. So, how do we transform the course?

In the early 90's CAD/CAM was not readily available, especially in the context of a one unit lab. The knowledge, time and money that had to be expensed inhibited prototyping. Well, about this time the Rapid Prototyping (RP) industry was just beginning. Cool Stuff and we got heavily involved with it from the beginning (reference 1). We could imagine the possibilities for the production of tooling and in the teaching of engineering design. We acquired our first systems in 1993 and started to use them in the course. However, there were problems with our infrastructure for the course. We couldn't yet support the rapid development of geometries in the timeframe we had. We were constrained by the lack of a computer lab or adequate software. Also, we lost the existing foundry lab when we joined the Manufacturing department to become IME and struggled for years just to run the course in the merged welding and foundry space. While we always could demo the concepts of rapid tooling we couldn't have the students do it in an engaging or meaningful manner.

So, as the years went by we were able to build the lab facilities that we could only dream about in the beginning. But, with over 150 (or more) students a quarter the high end RP (now called additive manufacturing AM) systems were a bottleneck in themselves due to their low

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production rate and high cost of use. While still explaining and demonstrating the possibilities of the AM processes we focused on the rapid machining of patterns. We have been quite successful in this and hopefully the descriptions of the details of the Course and the Laboratory will show this. But, the transformation is still on-going.

Details of the Course

IME 141 Netshape is a one unit hands-on laboratory course that meets once a week for three hours throughout a 10 week quarter. We have between 120 to 168 students each and every quarter. Each laboratory section is limited to 24 students for safety reasons, so every quarter we offer 6 to 7 lab sections. The students come mainly from Mechanical, Industrial and Manufacturing Engineering with representation from all other disciplines, such as Architecture. There are no perquisites for the course and it is quite impacted and, as such is mostly limited to those who need it for graduation. Demand would justify many more offerings. The population in the class differs greatly quarter by quarter. In the Fall it is block programmed for the IE and MFGE freshman while in the Spring it tends heavily towards juniors and graduating seniors. This makes it challenging to structure the content to keep all interested.

The lab is organized into a lecture (one hour)/lab activity (2 hour) structure. Each week the lecture covers one of the main processes of the field (Green Sand, Lost Wax, Tooling, etc.).

The lab work is divided into two main areas: the computer lab and the molding/casting areas. Typically the students are split between the two and are rotated to the other when they have finished the first set of tasks. This allows us to minimize the crowding and waiting in the hands-on areas.

However, on some days it is easy and desirable to accommodate everyone at once. This is evidenced by the casting portion of the Lost Foam lab where we can assemble, mold and cast everything in less than 30 minutes.

The computer work is comprised of two main areas. First of all there is the use of industry supplied case studies and interactive programs. These are excellent and have been developed by the professional societies in an effort to educate design engineers as to the capabilities of the industry and it’s processes. The case studies required are linked to the lecture subject of the day and are used to complete individual worksheets. These worksheets are reviewed at the beginning of the following week’s session and are used as part of the note structure for the final.

The second area of computer work are the CAD/CAM programs. We use MasterCam to generate the geometries and NC files for producing the Medallion patterns. AutoCad is used to generate the graphics necessary for the wax injection die plates. Inventor and SolidWorks will be used to generate the stl files necessary for the additive processes. The ability to customize their own castings (mass customization) has proven to be immensely popular with the students.

Course Description (From the catalog)

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Metal casting as a netshape process in manufacturing. Properties of molding materials and the methods of casting. Introduction to rapid prototyping. Pattern and casting design principles. 1 laboratory

Course Learning Objectives:
- Be aware of the fundamental steps used in the most common industrial casting methods.
- Be able to identify a casting process to meet a particular end requirement.
- Be able to explain the basic relationship between tooling, patterns, molds and castings.
- Be able to identify the key components of a mold and a gating system.
- Be aware of the application of newer prototyping methods ("patternless/toolless" for producing castings.
- Using a CadCam softwares (AutoCad,MasterCam), to create the geometry and subsequent NC code to machine a custom pattern for making a sand mold and a unique casting.
- Gain experience making prototype patterns and molds using additive methods and secondary take off processes.

IME 141 Netshape **Schedule of Subjects**

Lecture	**Case Studies**	**Lab Activity**
1 Introduction Safety	**AFS Metal Casting**: Mold structure **QIT** : The 5 major Casting Processes	Safety Orientation
2 **Precision Sand** -Caterpillar engine -Foseco Bell	**Transmission Case** **Landing Gear** Uplock Support CP keychain process	Mold and Cast CP key chains Start MasterCam Medallion tutorial
3 **Lost Wax** -Investment Casting: -Solid Flask - Ceramic Shell	**The Lost Wax Process** **Intermediate Lever Arm** in the BMW	Design Lost Wax injection molds Begin design Medallion pattern
4 **Lost Foam** - Lost Foam Process -Strom's Lost Foam -Future truck	**Aluminum Cylinder Block** for GM Truck **Floatwall Panels** for a Jet Engine Combustor (Lost wax verses Lost Foam)	Create the individual wax patterns Create the solid flask molds Work on Medallion patterns
5) **Green Sand** -Standard Green Sand -Edlebrock -Sinto FBO Flaskless system - DISA (Vertically Parted Flaskless)	**Ice Cleat** for the M1 Abrams Tank **Green Sand Notes**	Cast the Lost Wax molds Breakout and finish the castings Turn in the Medallion patterns
6) **Die Casting** -Overview Six processes	**Die Casting** Study Guide **Die-Cast Housing**:Thermoelectric Fan Case (Rubber Plaster Molding for RP)	Make the Medallion molds Modify Medallion pattern designs
7) **Rapid Prototyping** -Fused Deposition -Powder Based Systems	**Internal Interface Frame** for LCD Projector	Cast and clean the Foam Mustangs

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-Patterns, Molds
-Spray Metal
-Foam Machining Prototyping .

8) **Rapid Prototyping** **Simulations**: Mold filling and solidification
-Tooling Bottleneck Cast the Medallion Molds

9) **Review for Final** Cast Rapid Protoype molds

10) **Final** Finish up any project

Details of the Laboratory

The structure of the lab facilities is fundamental to providing the flexibility that the course needs. It is a space that is shared with our welding course and supports fourteen or more three hour lab sessions a week. It consists of a briefing room, a computer lab, the main lab area, a molding and prep area, two additive manufacturing rooms and a large covered outside work area. It's a good space that allows us keep to the students working and not just waiting in line to use a particular piece of equipment.

We have the traditional standard shop tools: drill presses, grinders, sanders, bead blasters, welding systems, etc. We also have the foundry specific equipment: sand mueller, burnout kiln, wax injectors, molding systems, etc. And, then we have our more modern tools: computer lab, three CNC mills, laser engravers, additive manufacturing systems, etc.

The computer lab is extremely important to the effort. It is the basis for the flexibility and the "mass customization" that we are trying to achieve in the course. The students use the computers daily to: complete their case studies, generate their CAD/CAM files and, run industrial software from the professional societies (ie NADCA's Die Casting). Typically, half of the students begin in the computer lab while the other half make their molds. After the molds are made those students go on the casting area and the computer group moves to the molding area, and so forth. This rotation, as groups finish certain process steps, allows us to run large numbers through small spaces.

Hardware:

The hardware we use are: the Inductotherm two furnace induction melting system, the three HAAS CNC mills (one Mini Mill and two Office Mills), two ULS laser engraving systems, a Zcorp Additive Manufacturing Powder Based Mold Printer and, several Additive Manufacturing Extruded Plastic printers. Figures 1 through 6 show some of the hardware in this lab. It is our intention to add about 6 of the small plastic printers to support the course and to investigate the robotic milling of sand molds.

Our capabilities are improving and we still have the capacity to add more.

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Figure 1) Induction melting system

Figure 2) HAAS CNC Machining Centers

Figure 3) ULS Laser Systems

Figure 4) Powder Based Mold Printer

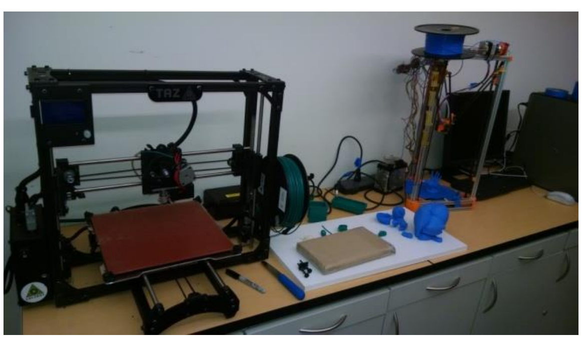

Figure 5) Additional Additive Systems

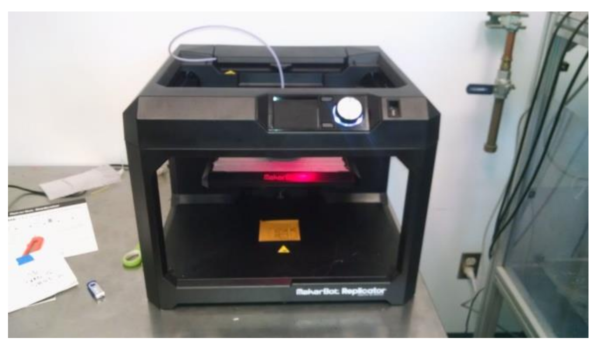

Figure 6) Additional Additive Systems

Student Projects

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The projects that we have the students do give them the "hands-on Learn by Doing" experience that we strive for here at Cal Poly. As mentioned earlier, the class is run not as a traditional three hour lab but as a combined one hour lecture and two hour lab activity. The key to being able to do this has been to streamline the processes of everything that we do. "Cycle time" is our mantra. We are constantly working on this. We would rather have the students finish early than wait for a bottlenecked process. By doing this we have freed up more and more time to add additional projects.

The projects that we currently doing are:

1) The CP Keychain Project (Team based) (see figures 7 through 12)

Teams of three. They make two molds per team.

Yield: Two CP key chains per student. Six key chains for the House.

Time: About an hour for all the teams to mold, pour and clean the castings.

In this beginning project the students work in teams of 3 to produce, pour and clean a mold to yield 6 key chains. They must successful produce the Cope and Drag mold halves, pour the mold, breakout the castings and finish them via sanding, drilling and bead blasting. They will use these skills when they do their individual medallion projects.

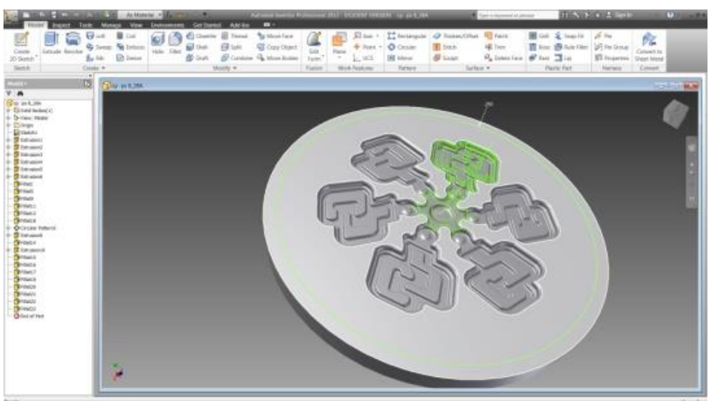

Figure 7) Master pattern CAD

Figure 8) Machined Wax Master

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Figure 9) Cope and Drag Tools

Figure 10) Casting the Key Chains

Figure 11) Casting the Key Chains

Figure 12) Finishing the Key Chains

2) The Lost Foam Mustang Project (Team based) (see figures 13 through 16)
Teams of three. They make one assembly per team.
Yield: One Mustang per student. One Mustang for the House.
Time: About 30 minutes for all teams to assemble and cast.
-We then let them cool during the lecture and break them out afterwards.

In this beginning project the students work in teams of 3 to produce, pour and clean a mold to yield 4 mustang paper weights. They must successful produce the lost foam pattern assembly, produce the mold, pour the mold, breakout the castings and finish them via sanding, and bead blasting.

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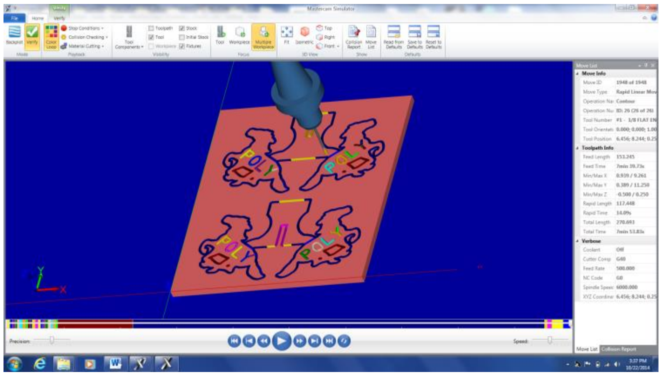

Figure 13) MasterCam Simulation

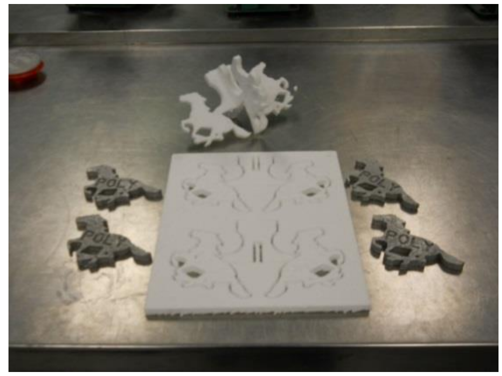

Figure 14) Patterns, Assembly, Castings

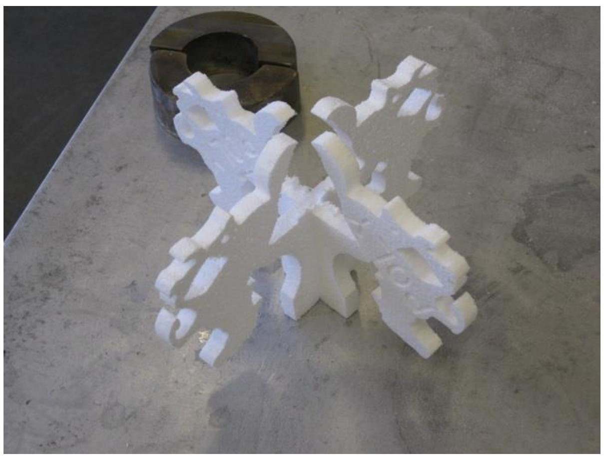

Figure 15) Foam Pattern Assembly

Figure 16) Casting

3) The Investment Casting Mold Project (Individual) (see figures 17 through 20)
Teams of three for the mold itself: six patterns.
Yield: Two key chains per student
Time: It takes a little over an hour for the students to inject their patterns and make the plaster mold.

In this project the students first work individually to create their own, unique geometry using AutoCad. They then use the ULS Laser engraving system to produce the wax injection die mold plate. This plate is then mated with an existing die and used to produce the wax patterns. Then students, now in teams of three, prepare the plaster I/C mold. Subsequently they pour the mold, break out their parts and do the usual sanding, grinding and drilling to produce these key chains.

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Figure 17)Wax Injection Plates

Figure 18) Injection Dies, Wax Patterns

Figure 19)Wax assembles

Figure 20) Flask ready for investment

4) The Medallion Project (Individual) (see figures 21 through 27)

Yield: The students are encouraged to make multiple molds from their pattern. Not enough for the whole fraternity but for the family.

Time: This is getting faster and faster. By using the new steel cope method we were able to mold, cast and clean 50 medallions in an hour.

In this final project students work individually to create their own, unique geometry using MasterCam in order to produce a pattern for sand molding. They learn how to create and modify features, re-tool path the part, simulate the machining process to see how their current design looks. They then machine the pattern, mold it, cast it and see if the result is what they intended. If there are problems they repeat the process until they are successful, using what they learn from each attempt to improve the result. This project is our best example of removing the foundry tooling bottleneck example with an "Art To Part"

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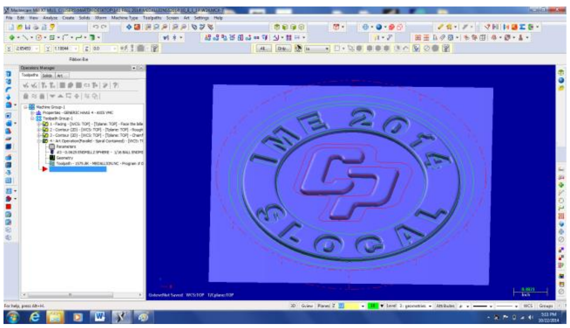
Figure 21) Machined Pattern and Casting   Figure 22) Patterns, Molds, Castings



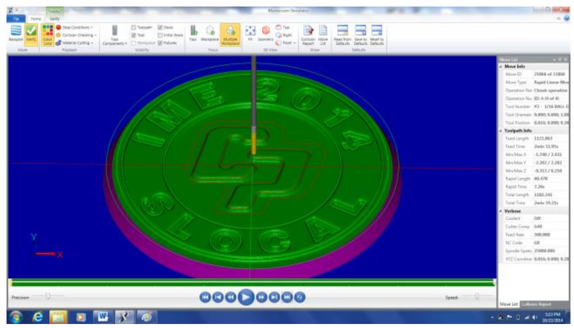


Figure 23) Modeling   Figure 24) Simulation

Figure 25) Pattern Machining   Figure 26) Patterns

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5) The Printed Mold demo: 3D Printed Molds and Castings (see figures 27 through 30)

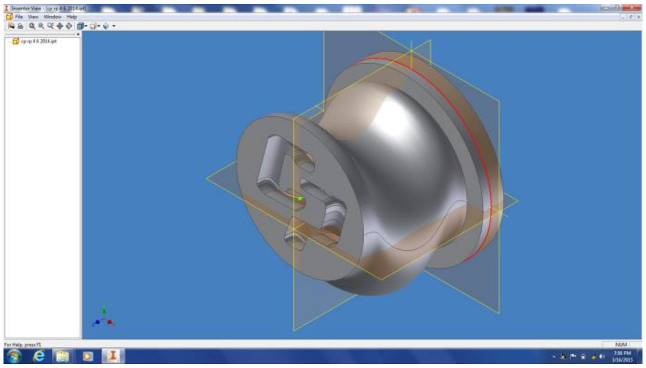

Figure 27) Inventor model of a mold

Figure 28) A 3D printer plaster mold and the casting

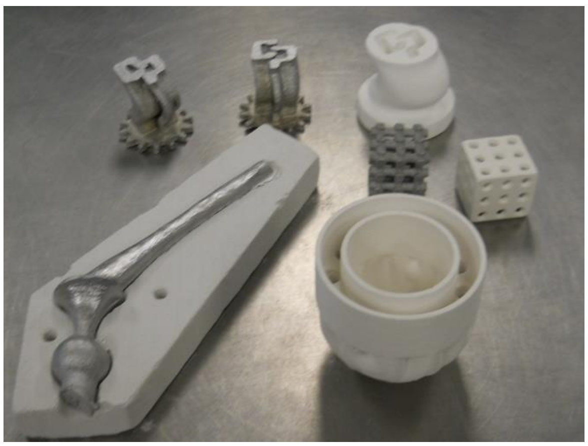

Figure 29) Various 3D Printed Molds

Figure 30) Cast 3D Printed 3D Molds

Conclusions:

A toolset in not a "bottleneck" is it is quick, inexpensive and easy to use. And towards this end we developed a capability to allow our students to get from Art to Part with their own design (see the Medallion Project below). This allows the student to "own" the process. What becomes important is not the process itself but what the students can do with it. If they are truly engaged in their lab work they will explore, experiment and learn.

We are not teaching "Foundry Engineering". We are not producing foundry engineers. Our mission is to teach design engineers about the capabilities of the industry. Additionally the

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content of the course is moving quickly towards more incorporating more additive manufacturing. There is a natural connection between metal casting and AM because of the need for tooling, patterns and parts and the shared netshape aspects of each. The toolsets for supporting both subjects greatly overlap. With the advent of the inexpensive 3DPrinters being able to provide patterns in the volumes and speeds that we need and with the streamlining of the foundry aspects of the lab (which frees up time for additional labs) this transformation is gaining speed. It always seems like we are just at the beginning of new and exciting things.

Acknowledgements

I would like to thank the Gene Haas Foundation and Haas Automation for their generous support of our lab and our efforts. I would also like to thank CNC Software (MasterCam) for their ongoing support, particularly Will Slota. Additionally, Frank Paton, Chris Miller and Rick Damiani of the Paton Group. Also, the American Foundry Society and the Foundry Educational Foundation must be mentioned for their ongoing and solid support of education. Finally I must recognize Dr. Jose Macedo for his unending support.

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1. Menon, Unny, and Martin Koch. "Rapid Prototyping for Foundry Tool Making: Curriculum and Industrial Projects." Solid Freeform Fabrication Symposium-1991 Proceedings. 1991.

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Flowgorithm: Principles for Teaching Introductory Programming Using Flowcharts

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Abstract

For students, the task of learning their first programming language can be compounded by the challenges of syntax, semantics and superfluous code. Historically, programming languages had a gentle learning curve requiring little syntactic or semantic overhead. Modern object-oriented languages, however, create a conceptual hurdle. Even the trivial Hello World program contains syntactic and semantic complexity far beyond the level of a beginning student.

This paper introduces Flowgorithm – a programming environment which allows students, with little to no programming experience, create programs using the visual metaphor of flowcharts. These flowcharts can be executed directly by the built-in interpreter allowing students to learn programming concepts before being confronted with language-specific syntax and semantics.

Flowgorithm provides an integrated learning path so students can apply their knowledge to a "real" programming language. The flowcharts can be interactively translated to over 10 programming languages. These include: C#, C++, Delphi/Pascal, Java, JavaScript, Lua, Python, Ruby, Visual Basic .NET, and Visual Basic for Applications. This allows a natural transition from the simple procedural logic of flowcharts to the more common object oriented languages used by universities today.

Beginning Programmers

Even the most gifted computer programmer, at one point, was a beginner. And as beginners, they have to struggle with the inherit challenges of their first language. Whether the language was BASIC, Pascal, C, Java, etc… they had to first handle the issue of syntax. Many languages have a syntax closely related to natural pseudocode while others can be either obtuse or symbolic. After basic syntax is understood, the programmer can then learn the semantics of the language. These can be implied by the syntax itself or can be, in many cases, unrelated. In this environment, students learn the basics of programming logic.

This learning curve can be gentle – allowing students to learn and understand concepts one at a time. Only the source code, that demonstrates the concept, is required. For example, the following is the solution for Hello World in QuickBASIC. There is little syntactic overhead which results in a program that is simple, short, and intuitive. Students can understand the program even though they may have never had any training in this language.

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```
PRINT "Hello, world!"
```

Figure 1: Hello World in QuickBasic

Unfortunately, the original procedural paradigm is being supplanted by the object-oriented paradigm. Under object oriented programming, everything is an object and all written code is related to class definitions and methods. While this approach offers flexibility and scalability, it requires students to define class constructs before even basic programming concepts are understood – such as expressions, variables, conditional logic, loops, etc… This results in a learning curve that has increased rather than decrease.

For example, the following is same Hello World example in the Java Programming Language. This code declares a class called *HelloWorld* with a single static method called *main*. Under the semantics of Java, the static *main* method is called when the Java runtime engine starts. The method then calls the *System* object's *println* method which prints the text to the console.

```
public class HelloWorld {
    public static void main(String[] args) {
        System.out.println("Hello, world!");
    }
}
```

Figure 2: Hello World in Java

While this is a valid solution for an object-oriented language, the beginner student is confronted with considerable syntactic overhead and a large number of advanced concepts. For beginning programmers, the emphasis should be on the *printlln*, the concept of output, and string literals. However, the student must type (and ignore) structures that define: a static function, a void return value, parameters, arrays, access modifiers, and more… This is compounded with the terse and symbolic notation of the C-family languages. While Java is both a robust and popular language, the rudimentary Hello World program is intimidating and overly complex for the beginner programmer.

Solution Requirements

The solution to this problem is a programming environment that allows students to learn programming concepts without burdening them with the nuances of a specific language. This includes syntax and language-specific semantics. However, it must be acknowledged that students will eventually learn another language. So, any solution must incorporate a learning path to other languages. As a result, the solution must adhere to the following principles:

1. Minimizes syntactic overhead
2. Clear semantics
3. Provides a mechanism to transition students to a major programming language

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1. Minimalizing Syntactic Overhead

To address the issue of syntactic overhead, this solution creates a programming environment that incorporates a graphical programming metaphor. Students will construct programs using graphical shapes to represent different components of an algorithm. This concept is not new, and has been implemented successfully by a myriad of applications.

When comes to the design of the graphical elements, should they be original or based on an existing industry standard? If the graphical elements are customized, such as in MIT's Scratch[1], then their use cannot be applied elsewhere.

Alternatively, flowcharts have been used throughout the industry since their original inception by IBM[2]. They are easy to understand and conceptualize. And, most importantly, they are able to represent all the common language constructs such as If, While, Do, For, etc… Introductory programming books often make use of flowcharts. This is the case with "Starting Out with Programming Logic and Design" by Tony Gaddis[3].

To adhere to a standard, flowcharts were selected as the graphical metaphor. This programming environment was named "Flowgorithm" which is a portmanteau of the words "flowchart" and "algorithm".

Mapping Flowchart Shapes

Most of the shapes found in modern flowcharts follow directly from the original IBM standard. Variations do exist, but the IBM format is the de-facto standard used in industry and academics. Flowgorithm maps each of the common programming logic tasks directly to the shape that best corresponds to its semantics. The Terminal Shape is used to represent the beginning and ending of a function. The Input/output shape is be used to represent information being read from the keyboard and information displayed to the screen's terminal. The Decision Shape represents an If Statement with the two branches – true and false (alternatively yes and no) – to represent the "then" and "else" clauses of the statement. The Subroutine Shape will represent a call to a function (i.e. procedure or subroutine).

The Calculation Shape represents variable assignment. It is important to note that mathematical expressions can be used throughout a program – such as output, variable assignment, operands of a Boolean expression, etc… So, the designation "Calculation Shape" is inheritably vague and misleading. As a result, this shape, in the context of this solution, will be referred to as the "Assignment" shape.

In addition, it is important for programs to contain internal documentation in the form of comments. In classical flowcharts, this information is provided using the Annotation Shape. To emphasize the inert nature of comments and to contrast from other shapes, Flowgorithm uses as variation with dashed lines.

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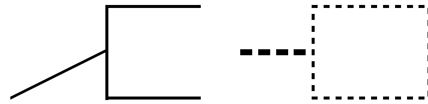

Figure 3: Comment Shape

In classic flowcharts, both loops and If Statements are constructed using the diamond "Decision" shape. While the two concepts are related, it requires the student to visually trace the lines to determine of the construct is loop or If Statement. To make the semantics clear upon visual inspection, Flowgorithm will use an elongated hexagon to represent a looping structure.

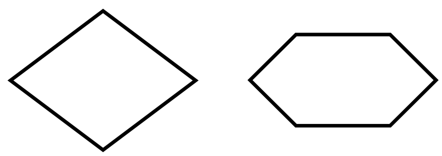

Figure 4: Conditional Branch vs. Loop Shape

This shape is classically used in flowcharts to represent a "preparation"[4] task - i.e. an action required for the flowchart to proceed. However, this shape is commonly used to represent looping in existing solutions. These will be covered later in this paper.

Finally, Flowgorithm uses explicit variation declaration. To represent a declaration, one of the original (yet rarely used) IBM flowchart symbols is used called "Internal Storage"[5]. The symbol is used to represent the computer's core memory – which is where variables are stored. Visually, the shape is similar to the Assignment Shape which underscores that both incorporate variable management.

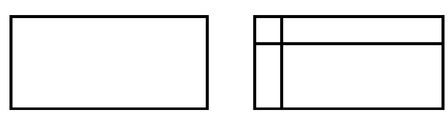

Figure 5: Variable Management Shapes

Flowchart Structure

There is no official standard to how the different graphical elements of a flowchart are arranged. Variations are common with shapes moving to the left, to the right, or bounding back to the top of the page. To make the flowcharts consistent in Flowgorithm, the arrangement of shapes will follow a set number of rules.

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1. The flowchart will start at the top of the page
2. Sequences of shapes (blocks of statements) will move downward.
3. The flowchart will move to the left or right only based on conditional logic.
4. Flow will move upwards only to complete a loop.

Loops and If Statements both contain a block of statements that are conditionally executed. To make these blocks visually distinctive, each block will either be located to the left (or right) of the shape. Hence, any blocks of statements should be discernable, to the beginner programmer, upon inspection. To keep the logical flow of pre-test loops, post-test loops and If Statements consistent, the flowchart will always branch to the right if the expression is true. The false branch will either fall straight down (for loops) or to the left (for If Statements).

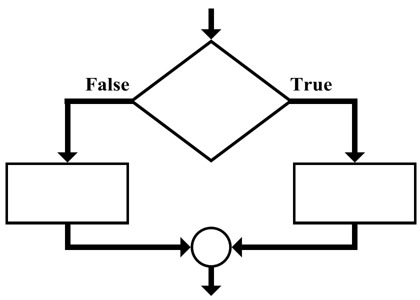


Figure 6: If Statement Layout

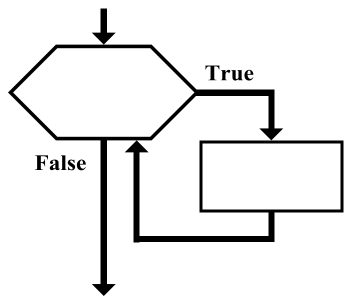
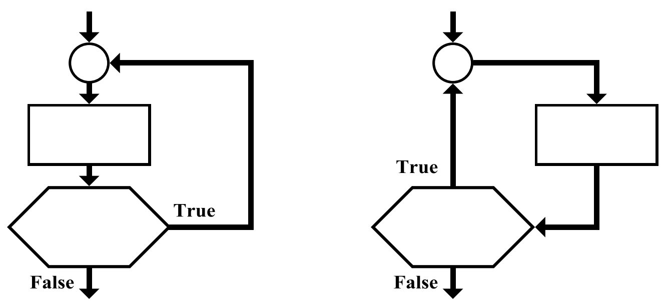


Figure 7: Pre-Test Loop Layout

Flowgorithm uses a different post-test loop layout than is used in typical flowcharts. To maintain consistency with the other two layouts, the post-test loops are arranged such that the body of the loop branches to the right. This allows the "block" to be visually distinct and also creates a clockwise motion which is consistent with the pre-test loop.



Classic Flowgorithm

Figure 8: Post-Test Layouts

2. Clear Semantics

Languages used by novice programmers should avoid semantic ambiguity and unpleasant "gotcha" moments. Beginning students have not had the training or the experience to logically dissect a logical error. If the error itself is caused by unintuitive operator behavior or an unexpected side-effect, it can be both frustrating and disheartening to a student.

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For example, one of the classic "gotchas" in the C Programming Language is the behavior of the division operator. The usual arithmetic conversions of the C language emphasize integer operations. This is a logical choice given that the language was developed in an era where many processors did not support floating point logic and C's emphasis on speed and efficiency[6]. The following C-Style program provides an incredibly difficult "gotcha" moment.

```
volume = 4 / 3 * M_PI * pow(radius, 3);
```

Figure 9: Incorrect Volume of a Sphere in C

While the example uses the correct formula to calculate the volume of a sphere, it contains a fatal flaw. Under the usual arithmetic conversions of C, if both operands are integers, then integer math is used. The "4 / 3" contains two integer literals resulting in the integer value "1" rather than "1.33333". For a novice programmer, it is not obvious upon initial inspection.

Moreover, some operators have different semantics based on the data type used. The most common form is the use of the "+" operator to both represent addition and string concatenation. Abstractly, the concepts can be seen as related, but for a student attempting to create a string from string literals and numeric values (either a variable or literal), the expression can be difficult to write and contain unintended side effects.

```
1 + 2 + "value"
```

```
"value" + 1 + 2
```

Figure 10: Java Concatenation Variations

In the first example, the integers 1 and 2 are being mathematically added and then concatenated with the text *"value"*. The result of the expression will be a string containing "3value". The second example, with only the order of operands changed, results in a drastically different result. In this case, *"value" + 1+ 2* will return the string "value12" rather than "value3".

The cause of the unexpected result is the order of the operands. The Java Programming Language uses the left operand to define the semantics of the operator. In the second case, "value" caused the addition operator to be interpreted as concatenation. This also chained into the second addition operator (since the first returned a string). It should also be noted that, in mathematics, the addition operator is defined as commutative and associative. Java's usage violates both properties.

Expressions

While the use of flowcharts minimalizes syntax (in fact, nearly eliminates it), any programming environment needs to implement mathematical and Boolean expressions. Unlike the shapes used in flowcharts, the symbols, used to represent operators, vary greatly between different programming languages. Expressions tend to fall into one of two categories depending on what other languages influenced them. The BASIC Programming Language uses readable operators

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such as AND, OR, etc. This contrasts with the C Programming Language which uses more symbolic notation such as &&, ||, etc.

If students plan to transition to major language, the question arises: which family should be used? Depending on the student's learning path, one set of operators will be compatible, while the other will not. To make it easier for students to take either path, Flowgorithm supports both sets. This will result in a number of redundant operators. The instructor can teach using either set – depending on the target language.

Operator	C	BASIC
Modulus	`%`	`mod`
Equality	`==`	`=`
Inequality	`!=`	`<>`

Operator	C	BASIC
Logical And	`&&`	`and`
Logical Or	`||`	`or`
Logical Not	`!`	`not`

Table 1: Redundant operators

To maintain simple semantics, the "+" operator will only be allowed for numbers. String concatenation will be achieved by using the Visual Basic styled ampersand "&". The C-Family languages also lack an exponent operator. Like the ampersand, Flowgorithm borrows the operator from the Visual Basic language. Both of these operators have clean semantics which also aid in code generation.

Variables

Flowgorithm uses strong typing in conjunction with explicit variable declaration. There a number of benefits to this approach:

1. Undeclared variables will cause an error – hence catching minor typos in the variable name. This is a common mistake by both novice an expert programmers.
2. The type of a variable is explicitly known.
3. Its usage of the variable is consistent throughout the program since its stored data cannot deviate from its declared type.

While not all languages make use of explicit variation declaration, it is an important concept to stress. If a student's learning path takes them to Python, for example, they will not need to type variable declarations. The student simply needs to omit typing a construct that they have been trained to understand. The student could be encouraged to create comments in the place of these declarations further documenting the program. However, if a student learns in an environment that uses implicit variable declaration, then the concept will be new when they are exposed to languages such as Java, C#, Visual Basic, and Lua. In other words, is far more beneficial for a student to learn disciplined programming and then by exposed to a weak-typed system, than to allow an undisciplined programmer to be exposed to a strong-typed system.

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One Way In, One Way Out

Ever since Dijkstra wrote his paper letter concerning the use of the Go-To Statement[7], the concept of Go-To Statements has been widely discredited for use in high-level languages. In fact, most high-level languages, such as Java, do not feature it. Flowcharts, like modern structured languages, are inherently one-way-in, one way out.

However, it is possible to add constructs that violate this principle. Quite notably, many languages feature Break Statements and Return Statements. Both of these concepts allow execution to jump directly out of a control-structure. They essentially function as a go-to, but only jump forward and prevent the "spaghetti-code" that caused derision with the Go-To. This is also true of the Return Statement except it jumps to the end of the function.

To maintain a strict adherence to one-way-in, one-way-out concept, Flowgorithm does not contain Go-To Statements, Break Statements or Return Statements.

3. Transition to a Major Language

While flowcharts are a standard method of describing an algorithm, they are not actually used to write programs. Rather, applications are written in Java, C#, and another major language. The problem then arises that if a student learns to program using flowcharts, how does it translate to actual knowledge in a University-level language?

Flowgorithm was designed to provide a learning path so students can take the knowledge and apply it to actual source code. Once the basic concepts are understood, students can generate source code from the flowchart. This code will not be exported separately to a file, but, instead displayed in an onscreen window that automatically updates as the flowchart is changed.

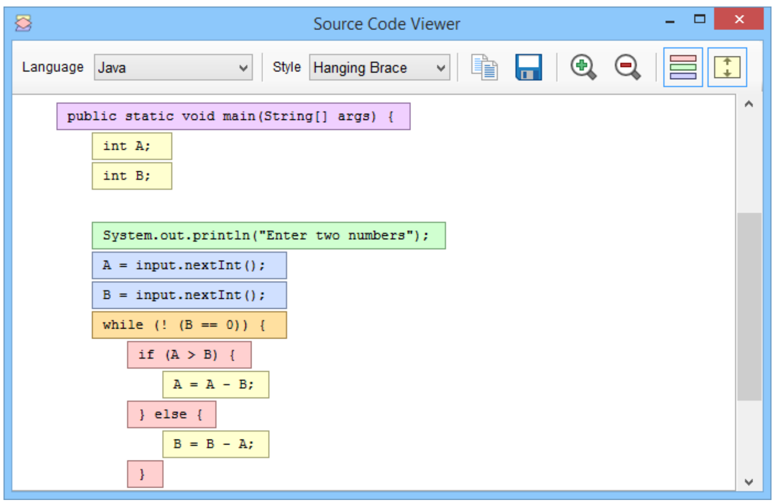

Figure 11: Source Code Viewer

To aid students visualize how a shape relates to its generated source code, both shapes and source code are color coded based on their functional category.

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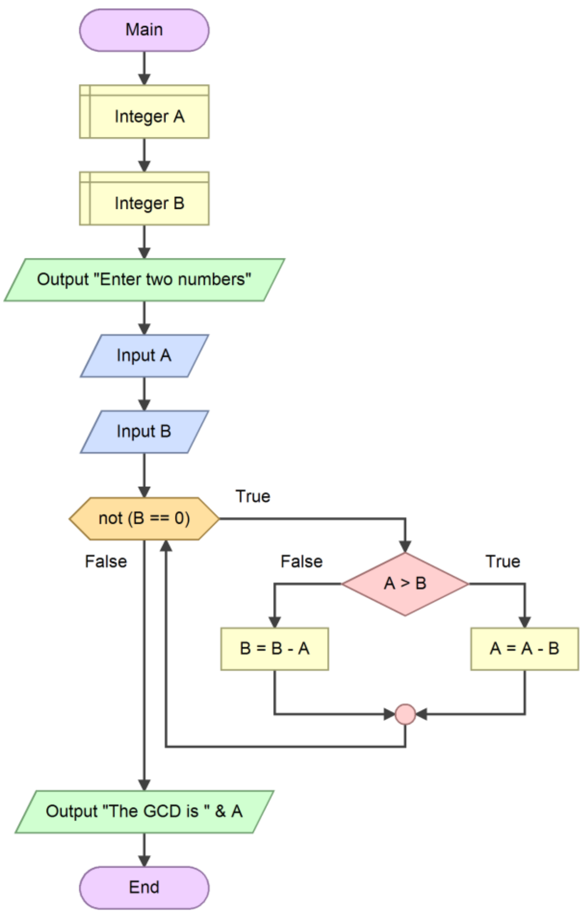
If the programmer is steps through the code, the current shape in the flowchart is highlighted as well as the corresponding source code. Each line of source code is linked directly to its parent shape – and will change colors based if the shape is selected, in error, or the current shape in an executing program.




```
import java.util.Scanner;
import java.util.*;
import java.lang.Math;

class MyProgram {
    private static Scanner input = new Scanner(System.in);

    public static void main(String[] args) {
        int A;
        int B;

        System.out.println("Enter two numbers");
        A = input.nextInt();
        B = input.nextInt();
        while (! (B == 0)) {
            if (A > B) {
                A = A - B;
            } else {
                B = B - A;
            }
        }
        System.out.println("The GCD is " + A);
    }
}
```

Figure 12: Flowchart of Euclid's GCD and Generated Code

As of this writing, the following programming languages are supported: C#, C++, Delphi/Pascal, Java, JavaScript, Lua, Python, Ruby, Visual Basic .NET, and Visual Basic for Applications.

Existing Solutions

Using the visual paradigm of flowcharts is not an original approach. Flowcharts were created for this very purpose, so creating a programming environment based them is merely a logical extension of the concept. The following are the three most notable:

- Visual Logic[8]
- LARP[9]
- RAPTOR[10]

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Each of these solutions successfully minimalizes syntax by using flowcharts. The design of the flowchart layouts and shapes varies between solutions, but, overall the notation is compatible. Unfortunately, these solutions do not sufficiently address the issues regarding semantics nor do they provide a learning path for students.

Future Work

Currently the software is only available on Microsoft Windows. Since the source was written in Microsoft C#, efforts will be made to cross-compile it to both Macintosh and Linux. Also, future versions will feature multi-lingual support. The project website, www.flowgorithm.org, will continue to be enhanced with examples, documentation, and relevant information.

Additional programming languages will be supported, as needed, by the Source Code Viewer. These include Perl, Objective-C, and Ada. The language itself can also be further enhanced with additional intrinsic functions and simple file I/O. The latter will only be added if it will produce valid programs in all the supported programming languages.

Conclusions

Besides addressing the aforementioned issues, great effort was made to make the application user-friendly and self-documenting. This includes features not mentioned in this paper such as the Variable Watch Window and Console Window. Student reaction to the software, as well as comments from the website, have been extremely positive.

The software was introduced in fall 2014, so more time is needed to fully measure any long term effects on student performance and retention. However, given student performance in "CSC 10: Introduction to Programming Logic", it is expected to be a beneficial tool.

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Iterative Design of Complex Systems

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Abstract

With recent advancements in technology and increasing demands of customers, today's software systems are more complex than ever. The complexity comes from difficult functional requirements, and from demanding non-functional requirements, such as very high availability, user friendliness, fast performance, and challenging security requirements[24].We are reaching the point of not being able to manage, design and develop our systems. In the classical waterfall model, design is done only once. This method cannot practically lead to an accurate design for complex systems, that too in current fluid market with demanding users and cut-throat competition. Most software projects using this methodology fail to meet their objectives. In incremental models, the whole cycle of software activities is repeated in increments, which again becomes restrictive. But in the iterative model, the design itself goes through several iterations until it has reached a point of accuracy which satisfies the designers, reviewers, practitioners, and stakeholders. Incremental design is about adding new elements, which one can choose to do iteratively, while iterating is about reworking and refining[16]. In this paper, we start by first discussing the basic principles of software design and then discuss how iterative design principle is crucial for complex software development. In an iterative design, a change-tolerant system can be built with desirable usability features.

Introduction

Software has been part of our society for more than 50 years. Modern day software development strives to create a balance between quality, cost and time. It's a difficult and painful job to create and deliver a cost competitive quality software in today's fluid and time-constrained market. Studies show that fixing problems after the delivery can cost from 60 to 100 times more than finding and eliminating the problems during the design phase. So why not find out these problems in design itself? In Iterative Design, prototyping, testing, analyzing, and refining a product is followed in a cyclic fashion by which we find out new bugs in each iteration of a design. In each iteration changes and refinements are made and new lessons are learned. In each iteration the practitioners do a research for informing and evolving a project and in each

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successive version of the system a more refined product is created. This process ultimately helps in improving the quality and functionality of the software design. Also, it is very effective when it comes to a complex system, as complex systems are very difficult to understand for both practitioners as well as the end-users.

Software Design Principles

The various elements of a software design can be derived using various methods which can be either data driven or pattern driven or object oriented. Regardless of the method that is used in the design, a set of design principles should always be applied to a software design[17]

1. Design should be traceable to the requirements model.

The elements of the design model should be traceable to the requirements model. Requirements traceability is complex, requiring integrated tool support and project team members who thoroughly understand the software development process. In Matthias Jarke's article "Requirements Tracing" [18], he defines requirements traceability as the ability to describe and follow the life of a requirement, in both a forward and backward direction, throughout the system life cycle.

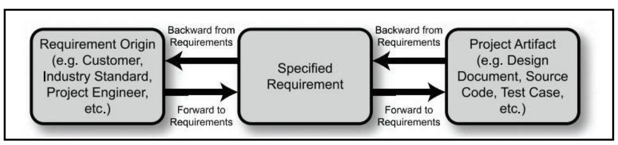

Figure 1: A view of software requirements traceability

2. Always consider the architecture of the system to be built.

Software architecture is the skeleton of the system to be built. It affects interfaces, data structures, program control flow and behavior, the manner in which testing *can be conducted, the maintainability of the resultant* system, and much more.

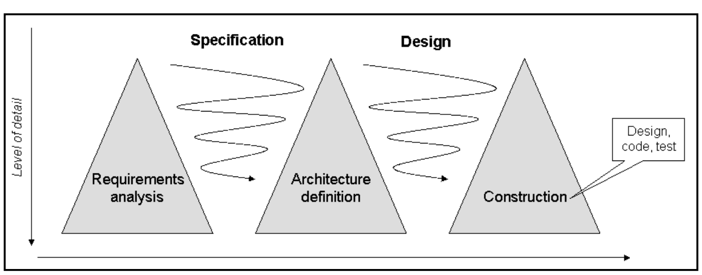

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Figure 2: Architectural definitions give input for system design and construction[20]

3. Design of data is as important as design of processing functions.

Data design is an essential element of architectural design. A well-structured data design helps to simplify program flow, makes the design and implementation of software components easier, and makes overall processing more efficient[3]. With a good data design, data access is faster and easily accepts future data enhancements.

4. Interfaces (both internal and external) must be designed with care.

"Interface design focuses on three areas"[17]: The design of interfaces between software modules; Design of interfaces between the software and other non-human procedures and consumers of information; and the design of the interface between a human and the computer.

5. User interface design should be tuned to the needs of the end user. However, in every case, it should stress ease of use.

“The user interface is the visible manifestation of the software. No matter how sophisticated its internal functions, no matter how comprehensive its data structures, no matter how well designed its architecture, a poor interface design often leads to the perception that the software is “bad”[17] User interface design is important for several reasons. SWEBOK Guide mentions that the user interface of a software should be designed to match the skills, experience, and expectations of its anticipated users.[26] The usability of the UI depends on how intuitive its design is. The better the UI, the easier it will be to train people to use it and more users will like to use it, increasing their satisfaction with the software.[23]

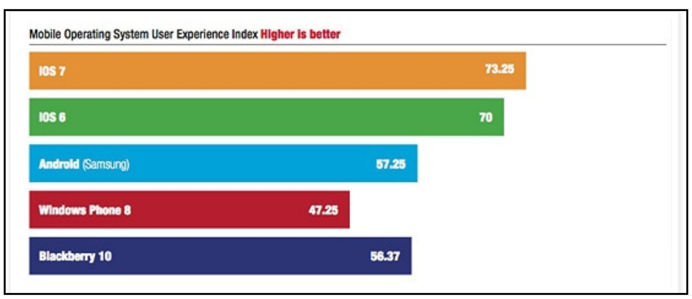

Figure 3: Results of a research immediately after the release of iOS 7.

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Above figure shows results of a comparison of iOS 6, iOS 7, Windows Phone 8, BlackBerry 10, and Android interface with a shell from Samsung. The comparison was conducted by Pfeiffer and they compared the convenience of the interface of the new mobile OS on the market. According to the researchers competition between manufacturers was precisely in the field of user interface.[19]

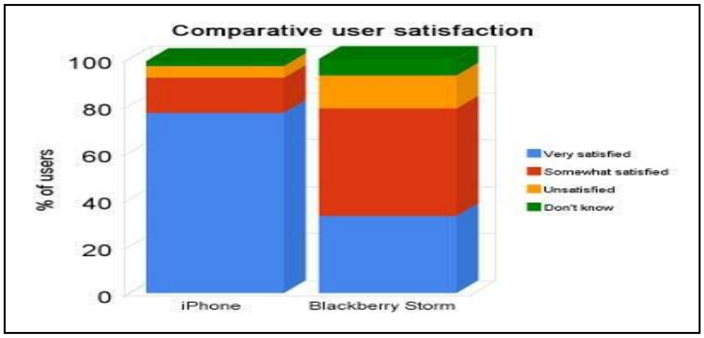

Figure 4: Result of an older ChangeWave survey carried out when iPhone came into market.

The above figure shows a survey conducted by an organization names "ChangeWave". The survey concluded that interface and overall user experience are much more important than "features" taken individually.[22]

6. Component-level design should be functionally independent.

Functional independence is a measure of the "single-mindedness" of a software component. The software that uses the property of functional independence is easier to develop because its functions can be categorized in a systematic manner. However, it should also be kept in mind that the effort (cost) to develop an individual software module does decrease as the total number of modules increases, as shown in figure below.[17]

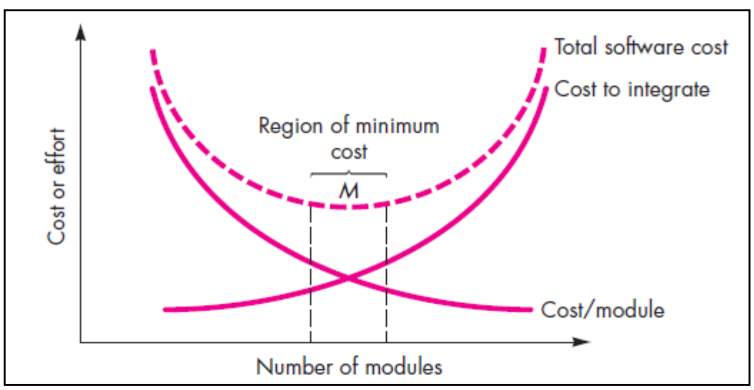

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Figure 5: Cost will be good only when we have an optimal number of modules.

7. Components should be loosely coupled to one another and to the external environment.

Coupling is measure of independence of the components. Coupling is achieved in many ways - via a component interface, by messaging, through global data.[17]

8. Design representations (models) should be easily understandable.

The purpose of design is to communicate information to practitioners who will generate code[17], to those who will test the software, and to others who may maintain the software in the future. If the design is difficult to understand, it will not serve as an effective communication medium. The SWEBOK Guide V 3.0 has mentioned several kinds of models which include use case diagrams, data flow models, state models, goal-based models, user interactions, object models, data models, and many others[26]. UML is very famous and a de-facto standard. The diagrams created using UML are editable and portable and there are plenty of tools in the market designed to create UML diagrams. Below figure shows a tree of diagrams supported by UML.

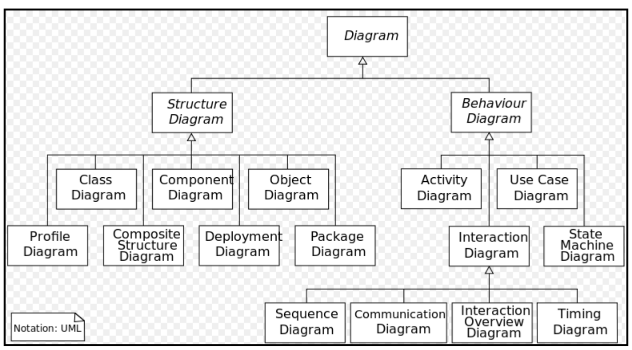

Figure 6: Hierarchy of UML diagrams supported in UML 2.2.

The above figure shows a wide range of diagrams that come under the UML diagrams to model the system from different perspectives. UML 2.5 has come up with 3 additional diagrams with the purpose of making UML simpler.

9. The design should be developed iteratively.

Like almost all creative activities, design occurs iteratively. The first iterations work to refine the design and correct errors, but later iterations should strive to make the design as simple as is possible. The most important role in a software development is played by Iterative design, *especially* when the system to be designed is a modern one. According to the SWEBOK Guide V

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3.0, "Iterative and adaptive methods implement software increments and reduce emphasis on rigorous software requirement and design"[26].

Why do complex systems need Iterative Design?

Iterative design methodology is an effective and powerful approach to designing complex software systems. In waterfall model, design is done only once. This method cannot practically lead to an accurate design for complex systems, that too in current fluid market with demanding users and cut-throat competition. Most software projects using this methodology fail to meet their objectives. In incremental models, the whole cycle of software activities is repeated in increments, which again becomes restrictive. But in iterative model, the design itself goes through several iterations until it has reached a point of accuracy which satisfies the practitioner, designer and the stakeholders.

Complex systems have structures that cannot be well understood at once so their design needs to go through several iterations. Conceptual integrity can be incorporated through frequent problem-solving cycles and refinements as each cycle proceeds. Without continuous improvement, any software system will suffer. It will not fit in the fast changing operating environments. In a surprisingly short time, the system will become “outdated”.

“A change-tolerant design process is more likely to result in a change-tolerant system which is an important aspect of software quality.”[5] Change tolerant systems adapt to business and technical changes economically. We have innumerous examples of successful companies using iterative designs. Why does Apple comes up with a new design of iPhone every year? Because customers will always want more, and with each new version comes the anticipation of better features as well. Apple has never failed its customers probably because of which a majority of users prefer an iPhone over other its other competitors.

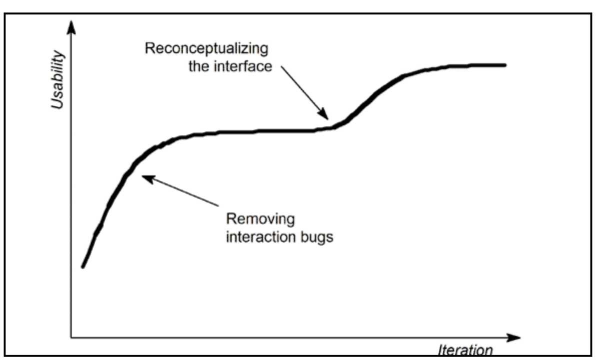

Figure 7: “Interface quality as a function of the number of design iterations.

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The above figure shows that the measured usability will normally go up for each additional iteration, until the design potentially reaches a point where it plateaus."[21.] The graph shows that usability increases when a design goes through iterations and flaws are constantly removed with detection. Because, a perfect design cannot be created in one go. It would need refinement. Refinement can be done by getting inputs from all stakeholders by showing the revised prototypes to them. Below diagram shows how such an iterative design is carried out to improve usability.

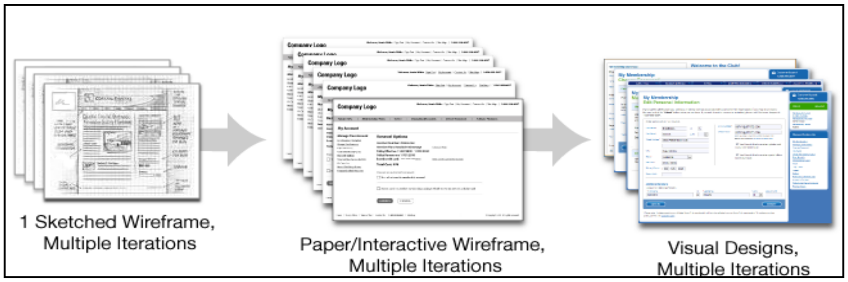

Figure 8: Iteration simply means to step through one design version after another.

"As agile methods become more popular, some view iterative, evolutionary, and incremental software development - a cornerstone of these methods - as the "modern" replacement of the waterfall model"[1].

How iteration helps in refining design

"Good design is a discovery process, done through short, repeated exploratory cycles." [5] "In a mathematical method of iteration, or successive approximation, a problem is solved by proposing a series of candidate solutions, each one building on the preceding attempt, until a desired degree of accuracy is achieved."[9] Software systems are no different from mathematics.

The early design is a prototype of a piece of the overall design. Early iteration should leave a wide range of options for implementing the rest of the system. Development will begin as soon as the initial high level design is available. In an iteration, you implement only the minimum amount of functionality necessary to demonstrate the core concepts of that iteration. The design will evolve in later stages and at each stage by following change-tolerant design practices. An iteration should be considered as a demonstration of a possible solution; it should not be considered the only solution. "An underlying principle of the iterative method is that until you have actually built what you are designing, you are not going to be able to fully understand it." [6]

"Figure 9" below shows how an iterative design process is carried out.

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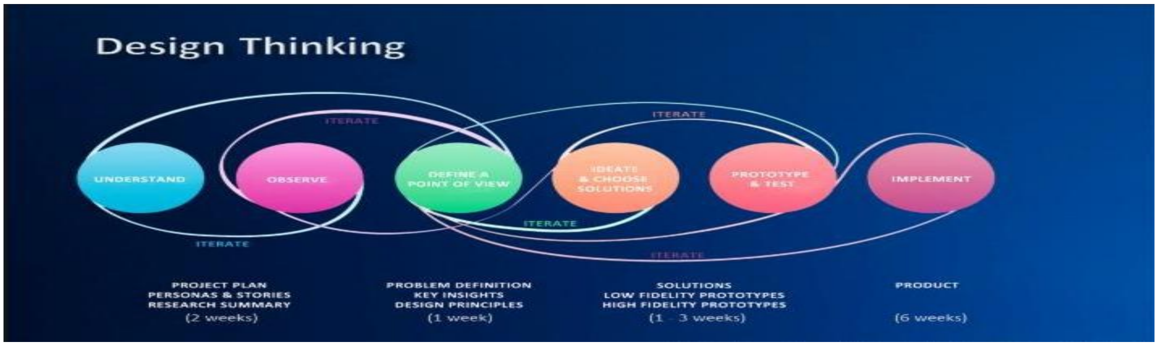

Figure 9: Design thinking is an experimental and iterative process[10]

But the real question is, When has enough design been done for developers to start working? That entirely depends on the developers and end users' expectations. Developer's role is to facilitate the design as it emerges and create a "change-tolerant" system.

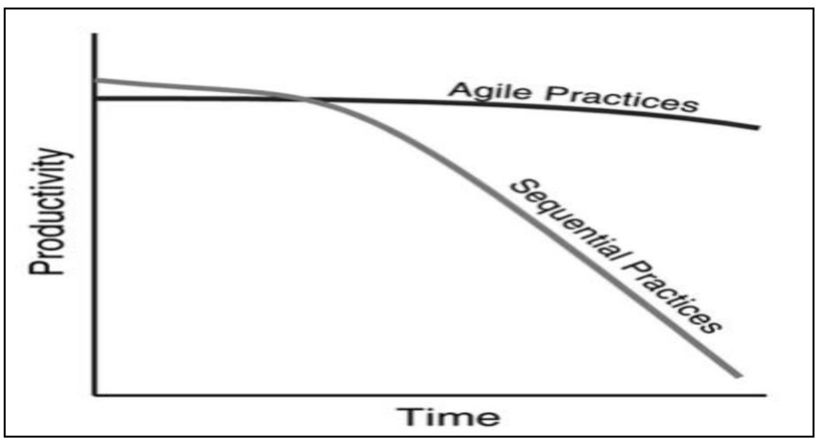

Figure 10: Continuously improving design sustains productivity

Innovations in Iterative Design

Possible solution could be having a "pre project" before the real project starts in which the user stories are finalized, smart uses cases are created and the wireframes are made. In next iteration, designer can work on the wireframes.

It is a good idea to make progress visible to both the development team and the customer. A very good method of doing so is burn charts used by Scrum to keep track of work done and remaining. A **Burn Down Chart** is a graphical representation of work left to do versus time left in the project. The outstanding work (or backlog) is often on the vertical axis, with time along

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the horizontal. A sample burn down chart is shown below. There are tools to create burn down charts like Google docs and Spreadsheet and desktop spreadsheet software.

Below is a sample burn down chart of a XYZ project (Source: GoogleDocs)

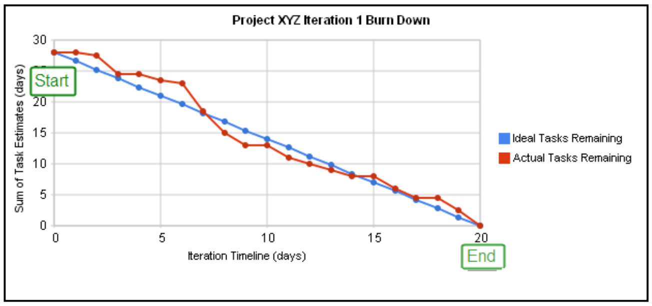

Figure 11: Burn Down Chart

Below is the diagram showing the model of an innovative agile development process "SAM" or the "Savvy Design process", which uses iterative design approach to software development process.

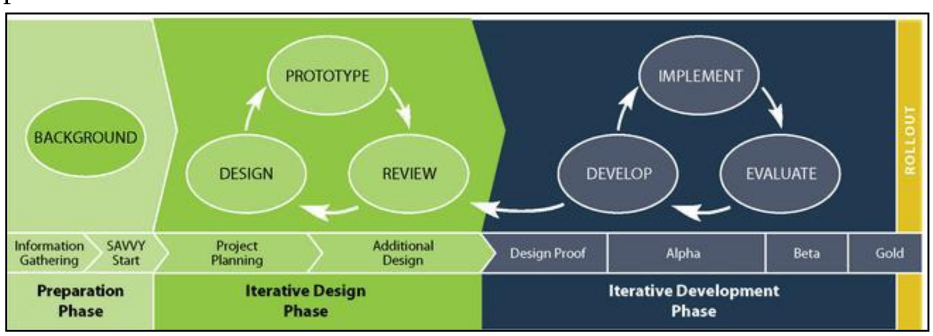

Figure 12: SAM process model

In their paper, Ploskonos and Uflacker [12] have classified modern design centric projects into "4 types, namely usability projects, capability projects, extension projects and innovation projects" and described how iterative design can be applied into all of them as shown in diagram below.

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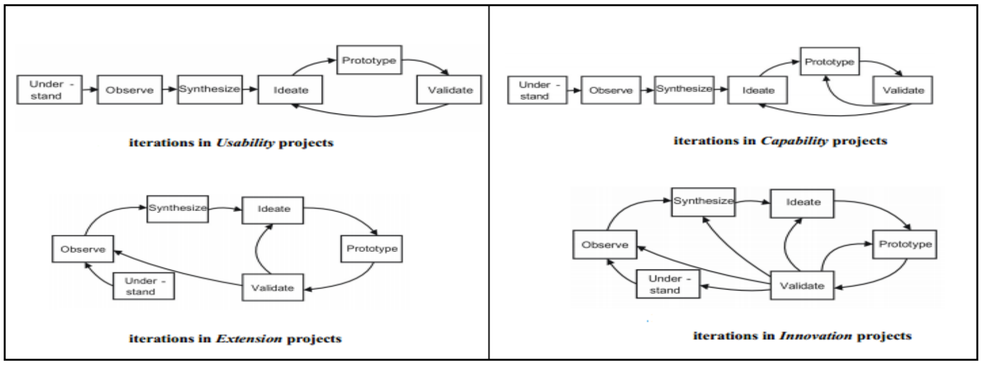

Figure 13: Iterations' use in design centric projects suggested by Ploskonos and Uflacker.

Complex User Interface Design

Today, user interfaces are complex software components, which play an essential role in the usability of an application. The design of UIs therefore, requires not only guidelines and best practices, but also a process including the elaboration of visual models and a standardized notation for this visualization. The development of user interfaces (UIs), ranging from early requirements to software obsolescence, has become a time-consuming and costly process[25] . Typically, the graphical user interface (GUI) of an interactive system represents about 48% of the source code, requires about 45% of the development time and 50% of the implementation time, and covers 37% of the maintenance time[14]. These figures, evaluated in the early nineties, are increasing dramatically with the spread of new interaction techniques such as vocal and gestural modalities, resulting in additional requirements[13].

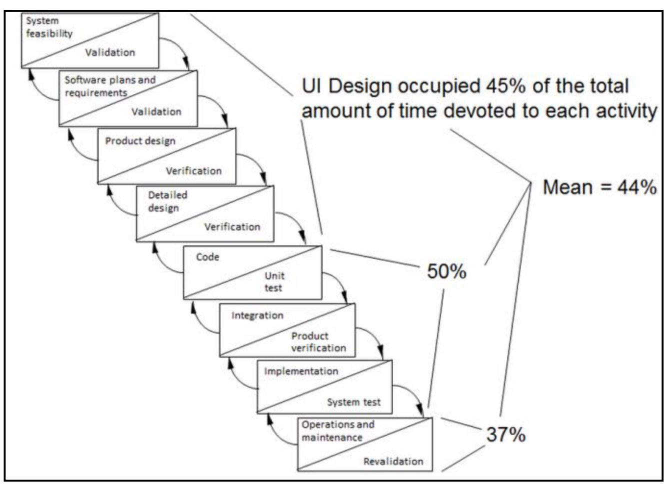

Figure 14: Distribution of UI development effort in a waterfall development life cycle.

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So far, UI designers have been using prototypes to model GUI. A great advantage of using prototype is that designers can focus on the usability of the screens without getting mired in the details of pixel perfect positioning and color schemes. Prototype is also iterative in nature as in a single step a perfect prototype cannot be created. In contrast to the other conventional software engineering methods where the software engineer begins development with the most understood portions first, prototyping method is used to understand the least understood aspects or components of the software first[26]. The prototyped product does not become the final software product without extensive development rework or refactoring.

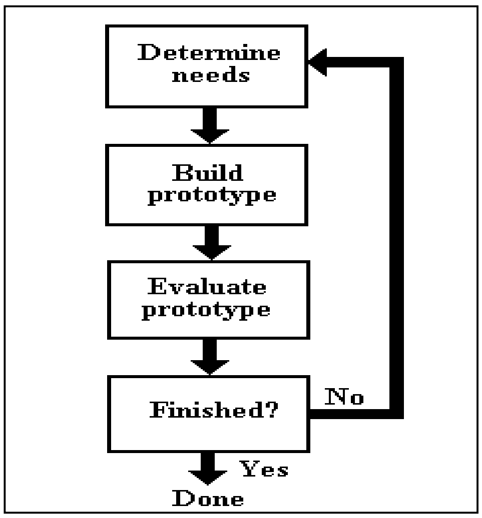

Figure 15: The "Iterative" steps of Prototyping[15]

Conclusion

An iterative approach gives us the opportunity to learn more and more about the system as we design it and delve into the deeper details of the product. In today's market, Agile is the most commonly used software development model. Most companies have accepted it and adapted it as their favorite philosophy for software design and development. "For anyone practicing one of the various flavors of Agile, this will all likely look quite familiar, and for good reason, since everything that converged under the Agile umbrella really are just different flavors of iterative (as well as adaptive/lightweight) development methodologies."[16] Unlike the traditional waterfall models, Iterative design empowers team members, as it helps in discovering problems earlier, get reliable user feedback in each iteration resulting in a good quality software, and team members spend less time documenting and more time on designing.

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Why Women Avoid Computer Science: The Influence of a Negative Stereotype

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Abstract

The gender gap in Computer Science is a well-known problem in the United States and many other countries of the world. Researchers have identified a number of factors contributing to the lack of attraction toward CS among women. One such factor is the "geek"/"nerd" stereotype associated with people in this field; a computer scientist is typically considered to be socially awkward and not fun to be around. Young women do not want to choose a career path where they would be surrounded by such people, and more importantly, they don't want to become one of them. In this paper we discuss certain social behaviors of some people in computing, both men and women, that contribute to the perception of a "computer geek" as a socially inept person. Recognizing and accepting the truth behind negative aspects of the stereotype, as opposed to ignoring or denying them, will help us get to the root of the problem and find effective solutions for it. In the conclusion, as a step toward changing this perception, we propose adding a required Social Skills and Etiquette course for computing majors in universities.

Preface

The author of this paper has been teaching Computer Science for over three decades: first fifteen years in the USSR and remaining years in the United States. During her extensive academic career she interacted with many students, educators, and professionals in the field of computing, as well as in other unrelated disciplines. She had ample opportunities to observe the behavior of men and women in computing, and compare it with the behavior of those that are outside of the field. Statements, opinions, and reasoning included in this paper are based on numerous discussions the author had on this topic with students, educators, and professionals in CS.

Introduction

Computer Science has always been a male-dominated field in the United States. The gender gap in CS has always been a concern, but toward the end of the 20-th century it became so wide that it turned into a serious problem drawing the attention of many in the fields of Computing and

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Computer Science Education. Throughout the last two decades a significant amount of research was carried out to identify factors contributing to the problem[4]. Numerous approaches were proposed and substantial efforts were devoted to closing the gap, yet the under-representation of women in this important field is still a major concern. Even with the dominating female presence in social networks and the increased use of computing tools and technologies in everyday life, the attraction toward Computer Science hasn't significantly increased among young women[7].

Ten years ago we conducted an extensive investigation and established that young women in the United States typically choose their career path based on what they aspire to be, and not necessarily based on what they are capable of[3]. Despite having the intellectual ability to be successful in computing majors, most women consider the prospect of a career in this field unattractive. Researchers have identified a number of factors contributing to the lack of attraction toward Computer Science among women[4,6]. One of such factors is the "geek" or "nerd" stereotype associated with people in this field[1,2]. There is even a term "computer geek" that is often used in reference to people in computing. This stereotype has some positive aspects; for example, a computer geek is perceived to be very intelligent and is viewed as the "go to" person for any technology-related issue. However, more influential are the negative aspects of this stereotype, particularly the perception of a geek as a socially awkward individual who is not fun to be around[5,9]. Young women do not want to be in a field where they would have to be around socially inadequate people, and more importantly, they don't want to become one of such people[8]. In addition, a computer scientist is stereotypically perceived to be a male[1], which gives young women even more reasons to think of Computer Science as an unsuitable career choice.

As much as we agree that stereotypes are often unfairly generalized perceptions, we should acknowledge that stereotypes do not appear on an empty place and usually they are based on real albeit exaggerated observations. We cannot help but notice that social traits of some computer scientists are fairly consistent with the socially awkward "geek" stereotype, particularly here in the United States. Unfortunately, these traits are not male-specific and can be observed in females as well, and thus they represent a big hurdle in attracting young women toward CS.

In this paper we want to take an honest look at certain socially inept behaviors of some people in computing and recognize that a problem really does exist. It is important to admit that there is a problem, since the acceptance is one step toward the solution. We believe that it is only to our benefit to face this problem and find ways to solve it, rather than ignoring it or denying that there is some truth to the socially awkward "computer geek" stereotype.

Clarifications

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In the following sections we discuss certain social behaviors exhibited by some people in the field of computing, both men and women, that contribute to the image of a socially awkward computer geek. It is important to emphasize that in our opinion this stereotype is widely exaggerated; we believe that most people in the computing field have none of the traits a computer geek is supposed to possess.

In our further discussion we will use terms "computer geek" and "geek" to represent those people in computing, men and women alike, who exhibit the specific inadequate social skill or behavior being discussed in that particular segment. We want to emphasize that this term is not representative of the majority of people in the field of computing.

Observed "geeky" behaviors

Correcting others: Computer geeks are intolerant toward any inaccurate piece of information or data; they feel compelled to correct someone else's even slightest mistake. A little blunder in a conversation most possibly will leave a "normal" person undisturbed. However, it will bother a computer geek and compel him/her to interrupt the "guilty" party to make a correction. Consider a scenario where a computer geek bumps into a friend who they haven't seen for over a decade. The friend happily exclaims: "Oh, it is so great to see you. I haven't seen you for 10 years. Last day I was …". More often than not a computer geek will be inclined to jump in with a correction: "Actually, it is 11 years". This behavior may be irritating, but it can be explained. It is important to know that the geek is not trying to undermine others and prove them wrong – all he/she is doing is trying to correct the inaccuracy in the released information. The reason of such behavior most possibly lies in the professional background of computer scientists who learn early on in their training that inaccurate data or information may lead to unforeseen consequences. In computer science there is an expression "garbage in, garbage out" which means that if you give wrong input data to the program, you should be ready for any problems, starting with wrong results and ending with the crash of the program. Thus, correcting any type of inaccuracy comes as a second nature to a computer geek, and an error, even as harmless as the one in the given example, in the brain of the geek is flagged as a source of potential disaster which needs to be eliminated without delay.

Being too detailed: Computer geeks are prone to provide too many unnecessary details. When responding to a question or a comment, they often give additional information and details, even if most of that information is irrelevant or unsolicited. For example, a geek may go on and on talking about when and where they bought their new pair of eyeglasses and why it was time to toss out the old one, even though all you said was: "I love your eyeglasses. Are they new?" Or they may tell you all about every member of their family explaining where they live and what they do, even though all you asked was: "Will your family be at your birthday party?" This

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behavior too may be attributed to the professional background and training of people in this field. In computer science the concept of completeness is very fundamental; every algorithm must be complete, specifications of a problem must be complete, and input data have to be complete as well. Computer scientists are trained to consider and analyze the full picture in a problem solving task, including every single piece of information, and work out a solution that covers all possible scenarios for the given problem. By providing a detailed answer to a question in each of the above examples, a computer geek is simply trying not to leave gaps in the information and thus eliminate any potential confusion or uncertainty you may have.

"Bumpy" conversations: Computer geeks, especially younger ones, are often lacking basic skills to carry an effective conversation. Typically, a smooth-flowing conversation involves back-and-forth dialogue where the two parties take turns in talking. For the speaking party it is important to follow the body language of the other to be aware of the signs signaling his/her intention to take a turn in talking. On the other hand, for the listening party it is important to pick up the signs from the speaking party indicating his/her intention to complete their turn of talking and switch to listening. Many computer geeks, men and women alike, are prone to not pay attention to those signals. Missing a sign from the talking party indicating an intention to stop, leads to a pause in the conversation and creates an awkward silence. On the other hand, missing a sign from the listening party signaling an intention to put in a word, leads to a long monologue and is simply rude. The ability to hold a smooth-flowing conversation with back-and-forth dialogue is a skill that can be learned, but first we have to recognize and accept that there is an issue.

Lack of interaction in a group: In a group setting computer geeks, men and women alike, tend to be quiet and reserved, and even seemingly uninterested. This behavior especially surfaces in situations when the group is diverse and includes people of different backgrounds and professions. The apparent detachment of geeks in a social situation is not due to have nothing to say or not being interested in the conversation. We believe it is mainly due to being socially inexperienced and not knowing how to interact with others; after all people in computing spend the majority of their time alone with the computer and most of their interactions with others are in the form of electronic communications.

Lack of social consideration: Computer geeks are prone to being socially unaware, which can be mistakenly interpreted as social indifference. This trait makes a geek seem inconsiderate and rude, and in some cases even hurtful. It is not uncommon for a geek to go on with their agenda and be completely oblivious to the needs of others around them. For example, a geek may be unaware that he/she is keeping someone else from taking their lunch break, or they may not realize that they are taking too much time figuring out what they want to order at Starbucks when there is a long line of people behind them. They may not notice that they are monopolizing someone's time when the latter has other work or people to attend to. A computer geek may not

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be aware that when three colleagues are travelling together to a conference, it is rude to socialize with only one of them, leaving the other feeling excluded. This type of behavior is upsetting, of course, but it is important to note that the geek is not intentionally being inconsiderate; geeks are simply unobservant and clueless of other people's emotions and needs. The lack of social awareness and consideration most possibly can be again attributed to the fact that people in computing spend the majority of their time alone with the computer; they are not used to being around people and they simply don't know how to be socially attentive and tactful. Pointing out these behavioral flaws may help them recognize the problem and work on improving their social skills and alertness.

Lack of social etiquette: Examples of computer geeks being unmindful of social etiquette can be found in many situations. If a geek is engaged in a conversation with someone, it is not unusual for him/her not to acknowledge a friend who is walking by (no hello, not even an eye contact). It is not uncommon for a geek to not offer a lift to a colleague who is going in the same direction and doesn't have a car. It is not unusual for a geek to not think of holding the door for someone behind him/her, sending a Thank You note to someone to acknowledge a kind gesture, or sending a Sympathy note to someone who just lost a loved one. It is important to note again, that the lack of social grace is not indicative of malice or contempt. Most possibly it is a result of being non-intuitive and simply not knowing how to behave in specific situations. Once brought to light, this type of behaviors can be corrected and social etiquette can be learned.

Conclusion

As in any field, in Computer Science there are people with different social skills – some people are suave and confident, some are shy and reserved, and others are simply awkward. While there are no generalizations on the social behavior of people in many fields, there is one for those in the computing: lack of social skills and inept behavior is perceived to be a trait of a computer scientist. Although we may argue about the fairness of this generalization, it is important to admit that a percentage of CS population may need some improvement in their social skills and behavior. As a step in the right direction toward eliminating the stereotypical perception, we propose adding a required Social Skills and Etiquette course for all computing majors in universities. By educating future computer scientists how to behave in social settings and how to be smooth, charming, and polite in their interactions with others, we will lose the negative stereotype and eliminate one major hurdle keeping women away from the field of computing.

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Internet Security and Its Impact on Online Education

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Abstract

This article presents an overview of internet security and how the security system impacts on the success of online education. The paper also reviews state of online learning and its future over traditional college and university based learning. It reviews the current state of internet security and explores different internet security threats and how it can be minimized. This article discusses different preventive strategies and techniques to protect internet servers and provide security to online education from such threats.

1. Introduction

For a millennium, universities have been considered the main societal hub for knowledge and learning. However, over the last several decades, the basic structures of how universities produce and disseminate knowledge and evaluate students have shifted in a new direction due to societal changes created by technology—computers, internet, instant messaging, e-mail, Facebook, and tweeter. The transmission of knowledge need no longer be tethered to a college campus. The technical affordances of cloud-based computing, digital textbooks, mobile connectivity, high-quality streaming video, and "just-in-time" information gathering have pushed vast amounts of knowledge to the "placeless" Web. This has sparked a robust re-examination of the modern university's mission and its role within networked society [1]. The Pew Research Center's Internet & American Life Project and Elon University's Imagining the Internet Center asked digital stakeholders to weigh two scenarios for 2020. One posited substantial change and the other projected only modest change in higher education. Some 1,021 experts and stakeholders responded - 39% agreed with a scenario that articulated modest change by the end of the decade. Most universities' assessment of learning and their requirements for graduation will be about the same as they are now. Whereas, 60% agreed with a scenario outlining more change: *By 2020, higher education will be quite different from the way it is today. There will be mass adoption of teleconferencing and distance learning to leverage expert resources. Significant numbers of learning activities will move to individualized, just-in-time learning approaches. There will be a transition to "hybrid" classes that combine online learning components with less-frequent on-campus, in-person class meetings. Most universities' assessment of learning will take into account more individually-oriented outcomes and capacities that are relevant to subject mastery. Requirements for graduation will be significantly shifted to customized outcomes* [1]. Here are some of the major themes and arguments they made:

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- *Higher education will vigorously adopt new teaching approaches, propelled by opportunity and efficiency as well as student and parent demands*
- Economic realities will drive technological innovation forward by 2020, creating less uniformity in higher education.
- "Distance learning" is a divisive issue. It is viewed with disdain by many who don't see it as effective; others anticipate great advances in knowledge-sharing tools by 2020.
- Bricks' replaced by 'clicks'? Some say universities' influence could be altered as new technology options emerge; others say 'locatedness' is still vital for an optimal outcome.
- Frustration and doubt mark the prospect of change within the academy.
- Change is happening incrementally, but these adjustments will not be universal in most institutions by 2020.
- Universities will adopt new pedagogical approaches while retaining the core of traditional methods.
- Collaborative education with peer-to-peer learning will become a bigger reality and will challenge the lecture format and focus on "learning how to learn."
- Competency credentialing and certification are likely…
- 'Tension pairs' were designed to provoke detailed elaborations

2. Pros and Cons of Online Education

As discussed earlier, taking courses or getting degrees in online are becoming normal part of education, and students are finding it beneficial and taking advantage of it. Because of that online schools have increased in popularity and competing with the established educational institutions. Therefore, universities and colleges throughout the nation are coming forward with their own online programs. When distance learning first became available, it offered a few online classes here and there, whereas today more and more schools are offering online degree programs. According to a 2010 Sloan Survey of Online Learning [2], there has been a 21% growth rate in online enrollment, a rate substantially higher than the 2% growth with higher education student population overall. But there is an ongoing debate on questions like "***Is an on-campus degree better than an online degree? Why are so many students choosing to pursue an online education?*** "
Below are the most common pros and cons of an online education [3]:

Pros of an Online Education

- Flexibility– The main advantage of online learning is that it overcomes the distance, time, and pace barrier, i.e., students can participate in classes from anywhere, anytime, and at their own pace. The technology of Virtual Classroom access makes possible for students to keep up with other responsibilities while taking courses towards fulfilling their program requirement. According to U.S. News and World Report [4], online education offers excellent options for veterans because it allows them to work and study at unconventional times, which they're used to in their line of work.

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- Availability of programs –More schools are offering online programs, increasing the available options and allowing students to search until they find one that meets their needs.
- Synergy –The online format allows a dynamic interaction between the instructor and students and among the students themselves. Each individual can contribute to the course discussions and comments on the work of others. The synergy that exists in the student-centered Virtual Classroom is one of the most unique and vital traits that the online learning format possesses.
- Self-motivation – Students can log into their programs at their convenience and learn at their own pace. If they're having difficulty with a course, they can take more time to study it.
- Student-centered - While students should read all of their classmates' contributions, they actively engage in only those parts of the dialog most relevant to their needs. In this way, students control their own learning experience and tailor the class discussions to meet their own specific needs.
- Level playing field - In the online environment, learners have a certain measure of anonymity. Discriminating factors such as age, dress, physical appearance, disabilities, race and gender are largely absent. Instead, the focus of attention is clearly on the content of the discussion and the individual's ability to respond and contribute thoughtfully and intelligently to the material at hand.
- Creative teaching - In the online environment, the facilitator and student collaborate to create a dynamic learning experience. The realization of a shift in technology creates the hope that those who move into the new technology will also leave behind bad habits as they adopt this new paradigm of teaching. As educators transform their courses to take full advantage of the online format, they must reflect on their course objectives and teaching styles. Many of the qualities that make a successful online facilitator are also tremendously effective in the traditional classroom.

Cons of an Online Education:

- Technology issues – Before any online program can hope to succeed, it must have students who are able to access the online learning environment. Lack of access whether it be for economical or logistics reasons will exclude otherwise eligible students from the course. For some students, the cost and geographical location can be a deterrent to access online programs. Also, sometimes, students with computer or Internet problems will be unable to complete their assignments or exams on time.
- Security threats –Security challenge for host server of Virtual Classroom is becoming a big obstacle of getting quality education through online. Security of emails, Instant Messaging (IM), chatting, Facebook, and tweeting of students' activities are becoming a challenge & headache for IT personnel. Different types of potential threats exist that can compromise test & quiz materials, assignments, and potential alteration of grades. Some of these threats and their possible remedy is addressed in this article.
- Technology literacy - Both students and facilitators must possess a minimum level of technological (computer & internet) knowledge in order to function successfully in an online environment. For example, they must be able to use a variety of search engines and be

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comfortable navigating on the World Wide Web, as well as be familiar with Newsgroups, FTP procedures and email. If they do not possess these technology tools, they will not succeed in an online program.

- Student limitations - While an online method of education can be a highly effective alternative medium of education for the mature, self-disciplined student, it is an inappropriate learning environment for more dependent learners.
- Limitations on Facilitator -If facilitators are not properly trained in online delivery and methodologies, the success of the online program will be compromised. An instructor must be able to communicate well in writing and in the language in which the course is offered. An online program will be weakened if its facilitators are not adequately prepared to function in the Virtual Classroom.
- Social interaction – Online students don't have the social interaction with fellow students, which can be helpful for study purposes.
- Student/Instructor interaction – Online students have limited interaction with instructors and may have to wait for hours for reply to questions.
- Motivation – Some students need the push to get to class. Online students who know they can do it at "their own pace" may procrastinate.
- Curriculum - The curriculum of any online program must be carefully considered and developed in order to be successful. Curriculum and teaching methodology that are successful in on-ground instruction will not always translate to a successful online program where learning and instructional paradigms are quite different. Online curriculum must reflect the use of dialog among students (in the form of written communication), and group interaction and participation. Traditional classroom lectures have no place in a successful online program. Education of the highest quality can and will occur in an online program provided that the curriculum has been developed or converted to meet the needs of the online medium.
- Transferring credits – Some schools still do not acknowledge online schools in the same light as on-campus schools, making it difficult to transfer credits to an on-site college.

3. Security overview

The success of Online Learning depends on how secure is the internet system, more precisely, how secure the web-server which providing the educational services is?
A secure security system has three main concepts: confidentiality, integrity, and availability. Confidentiality ensures access of information to authorized parties only, whereas integrity ensures transfer of unaltered data to the receiver. Availability ensures the client's accessibility. The secure website and web-server must address and safeguard confidentiality, integrity, and availability for Virtual Classroom system.

The internet security involves protection of internal and external risks to the website & webserver, client computing system, and the business systems to which it connects. External threats to an E-Commerce website come from many sources, including the electronic economic environment and risks associated with the external internet and related networks. Internal threats

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come from employees, the internal network and business processes, and from management. Fig.1 shows some of the vulnerable points in an Internet environment (reproduced from Boncella 2000 [5]).

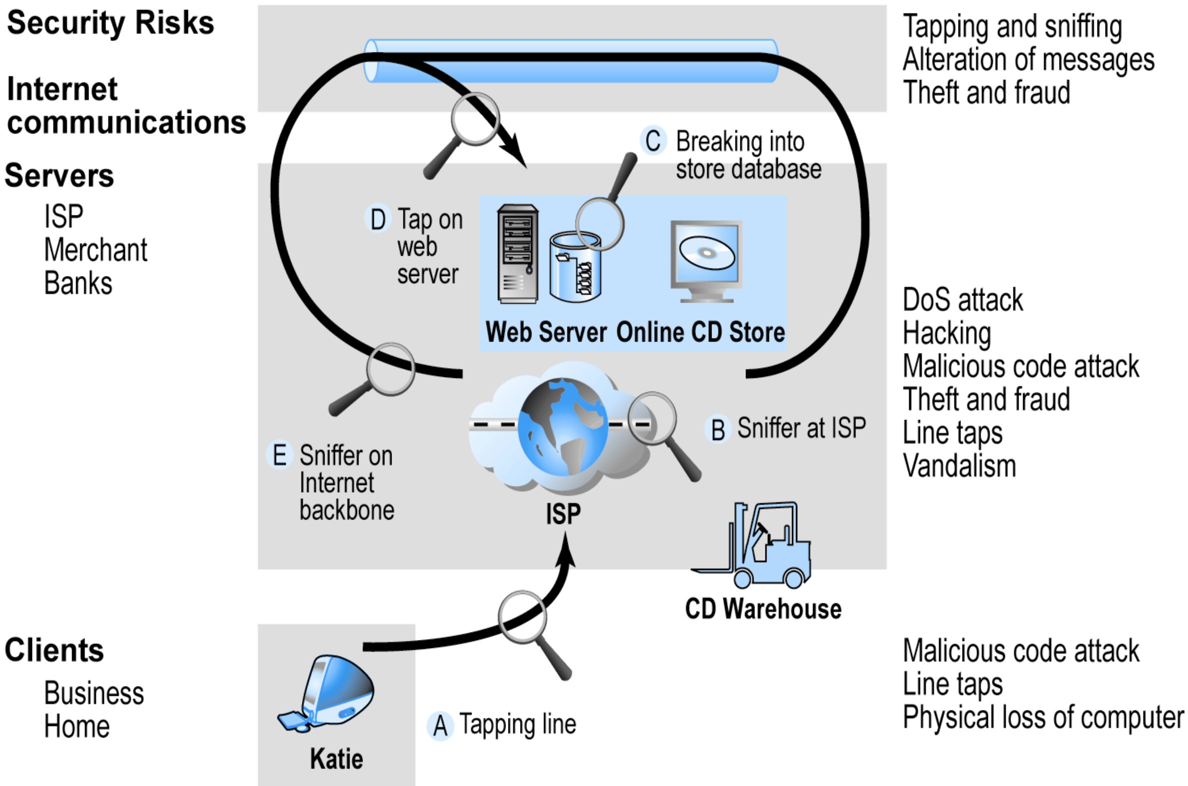

Fig. 1 **Vulnerable Points in an Internet Environment**

4. The Threats Posed to Internet Servers

An Internet Server provides services to the clients' transaction, e-mail services, and data-based activities for both front and back-end of an Internet system, hence, it is the most important device in the system that needs to be safeguarded. A server consists of the actual website which displays products & services, the customer database, and the payment mechanism. It can be viewed as the central repository for any "Internet Place of Business". Any successful attack to a server can be a serious blow to the system which can interrupt or destroy all the services provided by that server.

The primary purpose of any attackers or hackers is to access personal information such as Credit Card and Bank Account information; Phishing schemes, obtaining usernames and passwords etc. for exploitation. Threats can also come from technological failure where the perpetrator

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interrupts service of the server. This can be anything from a network not configured properly to data packets being lost, especially in a wireless access environment. Even poorly written programming code upon which an Internet site was developed can be very susceptible to these threats. Servers utilizing Windows based operating systems (Windows 2003 or 2008 or 2012 with IIS and SQL) are more vulnerable than those of Linux based system (ClearOS, Ubunto, Red Hat Linux, SUSE Linux, Apache, and MySQL).

4.1. Malicious Code Threats

The malicious, or rogue programming code can be introduced into the server in order to gain access to the system resources. Very often, the intent is to cause large scale damage to the Internet server. Some of these threats are discussed here:

4.1.1. Viruses and Worms

The most common threats are the worms and viruses. A virus needs a host of some sort in order to cause damage to the system. So for example, a virus needs a host file in which to attach itself to. Once that file is opened, the virus can then cause the damage. This damage can range from the deletion of some files to the total reformatting of the hard drive. A worm does not need a host to replicate, rather, it replicates itself through the internet, and can literally infect millions of computers on a global basis in just a matter of hours, and therefore, shut down the system. It is considered that worms are much worse than viruses.

4.1.2. Trojan Horses

A Trojan Horse is a piece of programming code that is layered behind another program, and can perform covert, malicious functions which comes with downloading software. For example, an Internet server can display a “cool-looking” screen saver, but behind that could be a piece of hidden code, causing damage to your system. One needs to make sure that whatever software is downloaded comes from an authentic and verified source, and that all defense mechanisms are activated on your server.

4.1.3. Logic Bombs

A Logic Bomb is a version of the Trojan Horse, however, it is event or time specific. For example, a logic bomb will release malicious or rogue code in an Internet server after some specific time has elapsed or a particular event in application or processing has occurred.

4.1.4. Port Scanning

This is listening to the network ports of the Internet server. When conducting such a scan, an attacker can figure out what kind of services are running on the Internet server, and from that point figure out the vulnerabilities of the system in order to cause the greatest damage possible.

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4.1.5. Trapdoors/Backdoors

In developing the code for an Internet web site, developers often leave "trapdoors" or "backdoors" to monitor the code as it is developed. Instead of implementing a secure protocol in which to access the code, backdoors provide a quick way into the code. While it is convenient, trapdoors can lead to major security threats if they are not completely removed prior to the launch of the Internet site. An attacker is always looking first for vulnerabilities in the Internet web server. Trapdoors provide a very easy vulnerability for the attacker to get into, and cause system wide damage to the Internet web server.

4.2. Transmission Threats

These threats and risks can be classified as either active or passive. With passive threats, the main goal is to listen (or eavesdrop) to transmissions to the server. With active threats, the intent is to alter the flow of data transmission or to create a rogue transmission aimed directly at the Internet web server.

4.2.1. Denial of Service Attacks

The main intention of this threat is to interrupt and/or deny services provided by the server. There is no actual intent to cause damage to files or to the system, but the goal is to literally shut the server down.

4.2.2. Distributed Denial of Service Attacks

Distributed Denial of Service (DDOS) Attack is similar to Denial of Service Attack with similar intention. In this scenario, many computers are used to launch an attack on a particular Internet web server. The computers that are used to launch the attack are called "zombies." These "zombies" are controlled by a master host computer. It is the master host computer which instructs the "zombie" computers to launch the attack on the Internet web server. As a result, the server shuts down because of the massive bombardment of bad information and data being sent from the "zombie" computers. A Distributed Denial of Service Attack is diagrammed as follows [6]:

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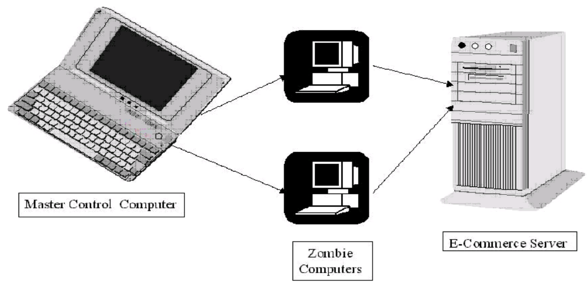

Fig.2 Diagram of a Distributed Denial of Service Attack

4.2.3. Ping of Death

Communication between client computer and the server takes place via the data packet which contains data and senders/receivers information. The normal data packet size that is transmitted across the Internet is about 1,500 bytes. With a Ping of Death Attack, a massive data packet of size 65,536 bytes is sent resulting overloaded memory buffers of the Internet web server, thus causing the server to crash.

4.2.4. Data Packet Sniffing

This refers to the use of Data Packet Sniffers, also known simply as "sniffers." While it is an invaluable tool to the Network Administrator for troubleshooting and diagnosis, an attacker can also use a sniffer to intercept the data packet flow and analyze the individual data packets. This is a very serious problem, especially in wireless networks, as the data packets literally leave the confines of the network cabling and travel in the air. Ultimately, Data Packet Sniffing can lead to hijacking sessions. This is when the attacker eventually takes control over the network connection, kicks off legitimate users (such as customers) from the Internet web server, and ultimately gains control of it.

4.2.5. IP Spoofing

The intent here is to change the source address of a data packet to give it the appearance that it originated from another computer. With IP Spoofing, it is difficult to identify the real attacker, since all Internet web server logs will show connections from a legitimate source. IP Spoofing is typically used to start the launch of a Denial of Service Attack.

4.2.6. **SYN** (synchronization) **Flooding**

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During the handshake process, the Internet web server becomes vulnerable to attacks. Phony messages (which appear to be legitimate) could be sent to the Internet web server, thus overloading its memory and processing power, and causing it to crash.

4.3 Threats to Internet Customers

4.3.1 Phishing Attacks

One of the biggest threats to Internet customers is Phishing attacks where group or individual send e-mail to users falsely claiming to be a legitimate enterprise in an attempt to scam the user into surrendering private information such as username, password and SSN. All of the confidential information collected by the "Phisher" can be used to damage Internet business.

4.3.2 Threats of 2014

As Internet service industry is expanding, new threats are surfacing regularly. In an article titled "*10 top security threats of 2014 (so far)*", author [7] reported that top three threats of the year are (i) 2014's threat theme: White-knuckle flaws in TLS/SSL protocols: Goto Fail, Heartbleed, POODLE, WinShock, (ii) Mega Retail Breaches, and (iii) Shellshocks**.** Experts are developing preventive measures of these threats, however, they are not fully implemented as of today, also, outcome of the implementation is not yet verified, and discussion of some of these measures are a bit more technical.

5. Protecting Internet Website

In order to protect Internet Business, Internet servers need to be protected from the threats which can be done two ways - Wireless Prospective and Hard-Wired Prospective [8].

From a *Wireless Perspective*, server threats can be neutralize by

5.1. Authentication - The Use of Secure Sockets Layer (SSL)
The basic essence of SSL is that, digital certificates are shared and transmitted between client's computer and Internet web server to verify theirs authenticity.

5.2. Encryption-The Use of Secure Shell (SSH)

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Encryption is a method of scrambling or encoding data to prevent unauthorized access (Symantec). SSH is a method that provides for an encrypted login connection to Internet web server.

5.3. Tunneling-The Use of Virtual Private Networks (VPN)

In addition of encryption, VPN also use the concept of "tunneling" for the added protection. The concept of "tunneling" means that the original data packet which contains the confidential information is placed inside another data packet for the extra layer of protection.

From a *Hard-Wired Perspective*, threats can be neutralized by

5.4 The Use of Firewalls.

Internet web servers are secured by installing Firewalls to enforce traffic control flow in and out of the servers. Firewall is a software or hardware & software combination program that controls the information packet traffic. Fig. 3 shows implementation of an Internet web server security using dual-homed firewalls (reproduce from [9]).

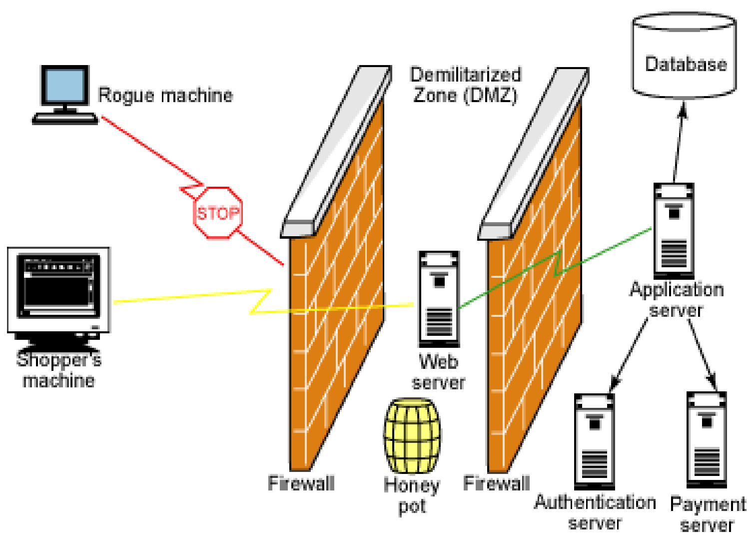

Fig. 3 Dual-homed firewalls Internet Web Server

5.5 The Use of Routers

Hard-wired firewalls are often called Routers which is a reliable protective measure for server. Here protective measures are firm-wired and installed within the routers.

5.6 The Use of Network Intrusion Devices (IDS)

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Firewalls and Routers are defensive tools to neutralize threats, however, IDS provide an offensive role, in that they not only defend Internet network, but they also actively look for threats that take place both outside and inside of the network, and alert the security administrator of the threat.

Firewalls are classified into packet filter, gateway server, and proxy server (Chan 2001).

The following is list of other preventive measures that can be implemented to minimize Internet threats [10].

5.7 A secure Internet platform

Internet web sites that use open-source Internet platforms are less secure than platforms that use sophisticated object-oriented programming language. Administrative panels of an Internet web site will be less vulnerable and inaccessible to attackers by placing them in company intranet system which are not available to public facing servers. A secondary authentication can be implemented to further safeguard the system which authenticates users within the intranet.

5.8 Don’t store sensitive data

It is always recommended that customer’s old sensitive data such as credit-card number, expiration dates, and card-verification value (CVV) codes should be pursed from the system database routinely. Enabling an address verification system (AVS) and requiring the credit card verification value can not only reduces misuse for the cards, it also helps keeping minimum sensitive data in the database system.

5.9 Set up system alerts for suspicious activity

Setting up system alerts for multiple orders placed by the same person using different credit cards, phone numbers that are from markedly different areas than the billing address and orders where the recipient name is different than the card holder name.

5.10 Layer your security

Introducing layers of security around the system is safer way to keep intruder away. Along with firewalls, adding extra layers of security to the website and applications ensures Internet environment is being protected from application level attacks such as SQL injections and cross-site scripting (XSS).

5.11 Provide security training to employees

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Employees need to be educated on the laws and policies that affect customer data and be trained on the actions required to keep sensitive data safe, they should never use e-mail, text or chat such a way that customer information can be revealed. Strict written protocols and policies can reinforce and encourage employees to adhere to mandated security practices.

5.12 Monitor Internet web site regularly

Real-time analytic tools like Woopra or Clicky allow to monitor how visitors are navigating and interacting with the website in real time, allowing to detect fraudulent or suspicious behavior. These tools send alert to phones when there is suspicious activity, allowing management to act quickly and prevent suspicious behavior from causing harm. Security personnel need to monitor regularly the host servers for malware, viruses, and other harmful software, and make sure the web host system has procedure in place that includes daily scanning, detection and removal of malware and viruses on the website. One needs to certain that the host server has back-up system to data back-up regularly, and has disaster recovery plan in place.

5.13 PCI scans and system Patch

Experts recommends quarterly Payment Card Industry (PCI) scans through services to lessen the risk of hacking attempts. Always update with new version if software like Magento or PrestaShop are being used to enhance security system. Patch the system regularly as a new version software such as Web server, third party code like Java, Python, Perl, PHP, ColdFusion, WordPress and Joomla are being released which are favorite target for attackers. Web apps, such as Xcart, OSCommerce, and ZenCart need to be patched regularly to safe guard the system.

As Distributed Denial of Service (DDoS) attacks increasing in frequency, sophistication and range of targets, Internet web sites should turn to *cloud-based DDoS protection* and managed Domain Name System (DNS) services to provide transactional capacity to handle proactive mitigation.

Many experts think utilization of cloud approach in Internet businesses will reduce operational costs while hardening their defenses to thwart even the largest and most complex attacks. Also, a managed cloud-based DNS hosting service can help deliver 100 percent DNS resolution, improving the availability of Internet-based systems that support online transactions and communications.

5.14 Biometric Technology

Some of the current cutting edge technologies that are working to make the Internet system more secure are *Biometrics* technology [11]. Biometrics is defined as the study of automated methods to uniquely identify humans based upon one or more of their physical or behavioral traits. Physical traits that used in Biometrics are fingerprints, eye retinas and irises, facial patterns or

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hand measurement, and DNA sequences. Techniques like signatures, gaits, and typing patterns are used in the Behavioral traits [12]. In some cases, voice recognition technique is also used to limiting access.

6. 2015 and Beyond

Future trend is surely to follow the track of 2014, however, a few new areas such as Android malware and Healthcare security, will definitely create more headache for Internet security industry.

Experts predict that 2015 will see attacks increase in trends toward larger Internet of Things (IoT) attacks. A late 2014 report shows that n*early 95 percent of enterprises are at least concerned about the security of the Internet of things* [13]. According to the article, IBM proposed a security model, which is a work in progress, and argued the following items will be needed for IoT implementations:

- A secure OS with firmware guarantees
- Unique identifiers
- Authentication and access control
- Data privacy protection
- And strong application security

With hacking, surveillance and retail breaches in every other headline, we can expect to see much more of this in 2015.

7. Preventive Strategies

As discussed in the previous sections, participants of Online Education encounter different threats and risk. In this section, some effective methods and tools are discussed. The organization of a typical Online Learning system may look like as shows in Fig. 4 [14]:

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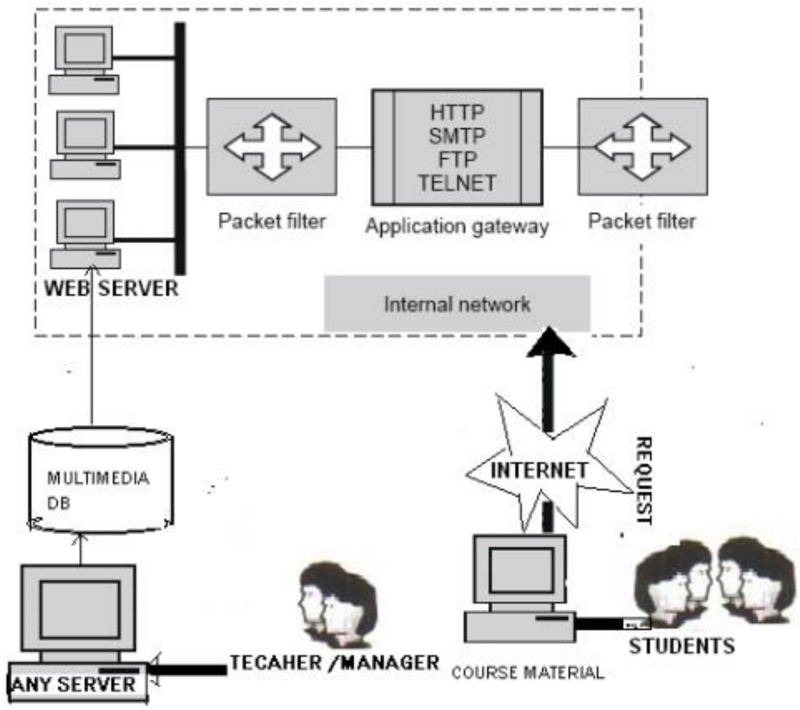

Fig. 4 Organization of a secure Online Learning system.

In the diagram above, we see that a secure system must have secure server system as well as secure transmission and reception system. Furnell and Kerwani [15] reported in their paper that Security requirements in course delivery must include a top-level view of an Internet based Online Distance Learning (ODL) solution, with a number of remote students accessing one or more LRP servers (Learning Resources Providers – which may be universities, colleges or, indeed, training departments within commercial organizations). The underlying requirements are considered in more detail in Table 1. This highlights the main issues that must be addressed and indicates whether they are of interest from the student and/or LRP perspectives.

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Security Issues	Student Interest	LRP Interest
Privacy and confidentiality of personal data	✓	✓
Security of service usage		
- Authentication and accountability	✓	✓
- Access control to LRP's system		✓
- Intrusion detection system		✓
Secure communications between staff and students	✓	✓
Security of payment		
- Non-repudiation of payment	✓	
- Integrity of payment	✓	✓
- Prevention of fraud		✓
Security of submitted work		
- Authentication	✓	✓
- Confidentiality	✓	✓
- Non-repudiation	✓	
- Integrity	✓	✓
Security of course material		
- Prevention of unauthorised access		✓
- Prevention from illicit distribution		✓
- Software licence control		✓
Digital certificate for course completion		
- Verification of issuing establishment	✓	✓
- Verification of certificate integrity		✓
Confidentiality of student grades	✓	✓
Reliability and availability of LRP's system	✓	✓
Confidentiality and secure conduct of exams/tests	✓	✓

Table 1 – ODL security requirements summary

Some of the tools or techniques which may be imposed to minimize Online Education threats are briefly discussed [14]:

7.1 Access control using Firewall

A firewall (Fig. 3) around the server has to be strong enough to prevent unauthorized incoming accesses. In practical implementations, a firewall is usually a combination of packet filters and application (or circuit) gateways. Sophisticated firewalls can block some incoming traffic but permit Online Education users (may be Students, Teacher, etc.) to the inside to communicate freely from the outside.

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7.2. Digital Right Management (DRM) on E-Learning assets

Asset of Online Educational system includes E-Learning content (Exam, Notes, Grade), Cryptographic key content, User personal data, Messages between users, Different group membership data, Network bandwidth, Message integrity and Message availability. Digital Right Management (DRM) makes the system safer for its contents. The system is working either in a distributed network or in Internet where multiple rights associated with learner, instructors content providers, administrators etc. come into play as content and services are created, distributed, aggregated, disaggregated, stored found and used. That is why digitization is needed. In a general sense, DRM should be used for license agreement and copyright protection or prevents copying.

7.3. Cryptography

Cryptographic algorithm are used to ensure the confidentiality of information and data are not disclosed to any unauthorized person or entity. There are two types of algorithms - *Secret-key algorithms* and public key algorithm are used for this purpose. In secret-key algorithms the encryption & decryption key is the same, it requires the sender and receiver to agree on the key prior to the communication, the main function of this algorithm is encryption of data. Public-key algorithms use one key (the public key) to encrypt messages or data, and a second key (the secret key) to decrypt those messages or data.
To authenticate a participant one can use *Digital Signature* and *Digital certificate*.

7.4. Elliptic Curve Cryptography (ECC)

Online Education system requires large amount of textual and non-textual messages need to be transfer among users, so ECC will be stronger option than any other cryptography techniques.

7.5. Biometric Authentication

Among all authentication techniques like passwords, smart card, Digital signature and digital certificate, there is no guarantee that dishonest Students will keep their password secret. Password might be misused at the time of submission of assignment, receiving question papers, etc. where biometric authenticity would give better security.

7.6. Digital Watermarking

This technique allows an individual to add hidden copyright notices, audio, video, image signals. So multimedia database server of Online Education system may be protected against unauthorized use by the way of digital watermarking.

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8. Conclusion

Online Learning represents a growing area of interest in the education and training domains. It is considered that this trend is likely to increase as a result of both improved technologies (e.g. for information delivery) and an increased emphasis on lifelong learning. As I have reviewed in this article, server security of Virtual Classroom is the most important issue for getting quality education through online. Security of emails, Instant Messaging (IM), chatting, Facebook, and tweeting of students' activities are becoming a challenge & headache for IT personnel. Different types of potential threats exist that can compromise test & quiz materials, assignments, and potential alteration of grades as discussed in this article.
Success of online learning depends largely on how secure the internet system is. As I have reviewed pros and cons of online learning and current state of internet security, it is apparent that much more need to be done both technologically and educating the clients in order to get desired level of quality education. Otherwise, some programs of some online institution will be more attractive than others, and that will make some students of similar program are more desirable or valuable than other.

As the use of Internet increases, so is the threats for the system. Everyday technologies both in hardware and software are improving, however, malicious threats for the Internet security are also evolving in new dimension. Threats like cloud security breaches, Facebook scams, Apple's rot, shellshocks, mega retail breaches etc. are putting new challenge to the system. The system can be secured more by improving security education for the ordinary user, application security, blame games and accountability problems among startups, and the security practices of retailers.

Level of security depends on the price of the system to be installed. It is important to consider pros of the security system offered against cons of reduced resources or increased system complexity. Minimizing the software available on systems reduces the doors available to abusers. Access control lists and execution control lists help in detecting unauthorized access. Remote administration tools should be tightly controlled to prevent abusers from using these tools for malicious purposes. Biometrics technologies appear to be very effective to control the access to the system.

As the discussion has highlighted, the types of control that are required (e.g. authentication and access control) are by no means unique to the Online Education system context and, in many cases, the strength of protection required will be considerably less than in other environments. What is required is a realization that, despite its benevolent objectives, the educational domain is not immune to security problems and, therefore, security controls need to be built into any online delivery frameworks that are to be used.

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Mapping between Computer Science Program Educational Outcomes, University Mission, and Student Outcomes

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Abstract

National University is seeking initial ABET accreditation for its Bachelor of Science in Computer Science degree program. The program has been in existence for more than 30 years and has more than 3500 graduates, but has undergone significant changes in preparation for ABET accreditation. Because of National University's strong assessment program, extensive evidence is available to demonstrate achievement of Student Learning Outcomes. However, the university has not had Program Educational Outcomes (PEOs) for its computer science and engineering programs in the past. In preparation for seeking ABET Accreditation; a set of three PEOs were first developed for the Bachelor of Science in Computer Science (BSCS) program in 2011. The PEOs were integrated into the university's extensive assessment review cycle, and mapped upward to the mission of the university and downward to the Student Outcomes. The three 2001 PEOs were expanded to four PEOs during review in 2014 by the BSCS External Review Board and the computer science faculty. Seven Institutional Learning Outcomes are integral to the National University mission. In order to describe how the Program Educational Objectives are consistent with the National University mission, a mapping was developed between the PEOs and the Institutional Learning Outcomes. In addition, in order to describe how the Student Outcomes prepare graduates to attain the Program Educational Objectives, a mapping was developed between the four PEOs and the eight formal Student Outcomes for the BSCS program. Student Outcomes are assessed in detail on an annual basis. Each Student Outcome is mapped to individual courses in the program, identifying where the Student Outcome is introduced, where it is developed and where it is mastered. Each Student Outcome is also mapped to the National University Institutional Learning Outcomes. This mapping to Institutional Learning Outcomes is critical to ensuring that each of ABET's student characteristics are enabled by the program. All of these mappings are discussed, along with the overall process for review of all aspects of the program, including Program Educational Objectives.

Introduction

National University was founded in 1971 and is the second-largest private nonprofit institution of higher learning in California and the 16th largest in the United States. It comprises five schools and one college: the schools of Business and Management, Education, Engineering and Computing, Health and Human Services, and Professional Studies, and the College of Letters and Sciences. National University is committed to accessibility and offers programs at 27 campuses in California and one in Henderson, Nevada, and online. At National University,

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courses are taught in a one-course-per-month format, giving students the ability to focus on learning one course at a time and the flexibility to pursue an academic plan at their own pace.

Since the BS Computer Science degree was first awarded by National University thirty-one years ago, the program has continually evolved to align with the improvements and innovations made in field of computer science. In keeping with the mission of National University, this degree was and still is targeted toward working adults, typically in their mid-30s, although there have been many younger and older students as well. Thousands of graduates have gone on to have successful careers in computer science and related fields. Hundreds have gone on to pursue and obtain master's degrees in computer science and related fields. This has been aided by a transition program that enables upper division BS Computer Science students to take and receive credit for some graduate courses required in the National University Master of Science in Computer Science program. A few of our graduates have gone on to receive doctorates in computer science and related fields.

A major change in the program came in 2005, when recommendations from a Five-Year Program Review resulted in more mathematics and science being added to the program. These changes were made to begin to align the computer science program with ABET/CAC Criteria[1].

Development of Program Educational Objectives (PEOs)

The Bachelor of Science in Computer Science program underwent its most recent comprehensive Five-Year Review in 2010. Two external reviewers who were also experienced ABET reviewers were invited to evaluate the program against ABET criteria as part of the comprehensive review. The majority of their recommendations were for changes related to ABET criteria. The 2011 Program Educational Objectives (PEOs) were an important result of their recommendations.

ABET requires periodic review of PEOs[2]. The 2011 PEOs were reviewed by a 10-member Advisory Board in 2014 and by all faculty teaching in the BS in Computer Science program. The review included comparison with PEOs for Computer Science degree programs at other universities. To name a few, the Advisory Board reviewed PEOs for Ohio State University[3], Catholic University of America[4] and Utah State University[5]. As a result of the review National University's BSCS PEOs were modified and expanded from three to four PEOs as follows:

Within a few years of graduation, graduates are expected to be:

- Engaged and active as practicing, responsible professionals in diverse career paths or successfully continuing their education in graduate school
- Participating in continuing education opportunities enabling them to understand and apply new ideas and technologies in the field of computing
- Effective communicators and team members
- Active contributors to their community and their profession

Consistency of PEOs with National University Mission

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National University has seven Institutional Learning Outcomes (ILOs)[6] which amplify the National University mission. Consistency between the BS in Computer Science PEOs and university mission are demonstrated by the mapping between the PEOs and the Institutional Learning Outcomes (ILOs) shown in Table 1.

All seven ILOs are related to BS Computer Science PEO #1. To be engaged and active in the computing profession requires applying information literacy skills to maintain currency. Practicing, responsible professionals also communicate daily with others in their profession and with other professionals in their enterprises. There is a direct relationship between displaying mastery of knowledge and skills in computer science and being engaged and active in the computing profession or related professions. Employers demand demonstration of cultural and global awareness and they require the ability to demonstrate professional ethics[7]. These abilities are essential to being active in any profession. Potential employers demand the ability to solve problems through research and critical thinking. And virtually all work in enterprises is done by teams of employees collaborating and using group processes.

	Program Educational Objectives (PEOs) Within a few years of graduation, graduates are expected to be:	**National University Institutional Learning Outcomes** (ILOs)						
		1. Apply information literacy skills necessary to support continuous, lifelong learning.	2. Communicate effectively orally and in writing, and through other appropriate modes of expression.	3. Display mastery of knowledge and skills in a discipline.	4. Demonstrate cultural and global awareness to be responsible citizens in a diverse society.	5. Demonstrate professional ethics and practice academic integrity.	6. Utilize research and critical thinking to solve problems.	7. Use collaboration and group processes to achieve a common goal.
1	Engaged and active as practicing, responsible professionals in diverse career paths or successfully continuing their education in graduate school	X	X	X	X	X	X	X
2	Participating in continuing education opportunities enabling them to understand and apply new ideas and technologies in the field of computing	X		X			X	X
3.	Effective communicators and team members		X		X			X
4	Active contributors to their community and profession		X		X	X		X

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Table 1 Mapping of Program Educational Objectives to National University Institutional Learning Outcomes

PEO #2—understanding and applying new ideas and technologies in computing— cannot be accomplished without ILO #1, because graduates must be able to apply informational literacy skills to learn about new ideas and technologies as they emerge. And graduates must build on the knowledge base and skills they acquired through their degree program. Applying new ideas and skills requires research and critical thinking. And, applying new ideas and technologies always takes place in collaboration with others, using group processes.

PEO #3 is about being effective communicators and team members. This concept is contained in each of Institutional Learning Outcomes 2, 4 and 7. ILO #2 states that our graduates will be able to "communicate effectively orally and in writing and through other appropriate modes."

ILO #4 adds to this the ability to "demonstrate cultural and global awareness to be responsible citizens in a diverse society," while ILO #7 states that our graduates will "use collaboration and group processes to achieve a common goal." PEO #3 summarizes these three ILOs into a single statement.

PEO #4 says program graduates will be active contributors. Active contributors at every level must be able to communicate effectively, utilizing all the means of communication as described in ILO #2. Contributing actively implies the ability to persuade others. Persuading people requires awareness and sensitivity to cultural and global issues, as described by ILO #4. Employers, as well as the public, require ethical contributors in the workplace, as described in ILO #5. Being an active contributor implies the ability to work with others in groups to collaborate effectively to accomplish a common goal, as stated in ILO #7.

Relationship Between PEOs and Student Outcomes

The National University Program Learning Outcomes for the Bachelor of Science in Computer Science (BSCS)[8], which ABET calls Student Outcomes (SOs), address the foundational science and mathematics skills that assist our graduates to become lifelong independent learners. As they are achieved, the Student Outcomes (SOs) enable students to further develop their formal problem solving and analytical skills to remain relevant in the field. The outcomes also address student abilities to design and develop multiple solutions and develop an ability to compare and contrast different solutions and their implications.

Exposure to relevant and current technologies in computing helps students quickly become contributing members of any development team when it comes to identifying and utilizing tools and techniques that can accelerate and optimize design and development. Knowledge of relevant ethical issues and ability to collaborate and work as a member of a team are valuable skills that can help students maintain their positions in the work environment, be successful, and potentially take on leadership roles. These concepts are summarized in Table 2 and further developed in the paragraphs below relating attainment of each SO to attainment of each PEO.

Table 2 lists the four PEOs in an abbreviated form, in the four right-hand columns. The rows numbered 1 through 8 list the eight Student Outcomes for the National University BS in Computer Science. In many ways, each SO contributes to all of the PEOs, but it is helpful to

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distinguish cases where a SO is a primary contributor to attainment of a PEO, from cases where it is only one of several contributors to attainment of the PEO. The intersections of the PEOs and the SOs contain a "P" for when that SO is a primary contributor to the corresponding PEO, while they contain a "C" for when that SO is a contributor to the corresponding PEO, but not necessarily a primary contributor.

Knowledge of mathematical foundations, algorithmic principles, and computer science theory, as listed in **SO #1**, is fundamental to success in the computing profession. The skill of applying this knowledge to modeling, design and optimization of computer-based systems enables students to succeed in finding employment and advancing in the computing field or in pursuing graduate study. Therefore, SO #1 is fundamental to PEO #1 – being engaged and active as practicing responsible professionals in diverse career paths or successfully continuing their education in graduate school. At the same time, SO #1 contributes to PEO #2, because it provides the base on which understanding emerging ideas and technologies in computing is built. The skills developed through the courses associated with SO #1 enable graduates to independently conduct research on new ideas and technologies in computing and to apply them. As graduates of the program expand their ability to absorb and apply new developments in computing, they develop and become recognized as active contributors to their community and profession – PEO #4. Becoming active contributors rests on the base skillset that is the outcome described by Student Outcome #1.

Student Outcome 2 describes the ability to break a problem apart into its various components, then design and develop software and/or hardware to address each of the components, and finally combine all of the pieces into a solution to the problem. This is a fundamental outcome of any computer science program. In many ways, this student outcome is the most important of all the Student Outcomes to achieving success in the variety of career paths that are open to graduates or in continuing their education in graduate school. SO #2 is a primary contributor to PEO #1. As graduates grow in their ability to analyze problems, they also grow their ability to break down problems into components and to apply new ideas and technologies in solving those problems. Therefore, SO #2 is a contributor to the achievement of PEO #2. Analyzing a problem and designing the computing requirements appropriate to its solution often requires groups of students to learn to work together as team members, which develops them as effective communicators, enabling PEO #3. As this ability continues to develop with lifelong learning, graduates naturally achieve PEO #4, becoming active contributors to their community and profession.

Implementation of a computer-based system, process, component, or program, as described in **SO #3**, is where the completed computer system, process, component or program is released for sale or rolled out to users or customers. To remain viable, businesses need to deliver real working systems, processes, components or programs and associated updates. To remain employed or to successfully continue their education, graduates need to know how the implementation process works and to both do it themselves and work with those who are doing it. Therefore, SO #3 is a primary contributor to PEO #1.

New ideas and new technologies can dramatically influence the implementation process. As graduates grow their abilities, they also grow their ability to participate successfully in continuing education as they recognize what new ideas and technologies can be used to improve implementation processes, to make them faster, less expensive, or closer to meeting the requirements of customers. Therefore, SO #3 also contributes to PEO #2. Implementation of a computer-based system, process, component, or program requires teamwork and effective communication as described by PEO #3. As graduates become more expert in the implementation process, they become active contributors to their community and the profession, as described by PEO #4.

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SO #4 is supported by courses in which students study and examine case studies of legal issues and ethical predicaments relevant to computing and computer systems. Being active contributors to their community and their profession requires a strong understanding of and appreciation for the impact of computing on individuals, organizations and society, including ethical, legal, security, and global policy issues. SO #4 is a primary contributor to PEO #4.

Student Outcomes Upon successful completion of this program students will be able to:		**Program Educational Objectives** - Within a few years of graduation, graduates are expected to be:			
		1. Engaged and active… or successfully continuing education	2. Participating in continuing education … enabling them to understand and apply new ideas and technologies	3. Effective communicators and team members	4. Active contributors to their community and profession
1	Apply mathematical foundations, algorithmic principles, and computer science theory in the modeling, design and optimization of computer-based systems.	**P**	**C**	**C**	**C**
2	Analyze a problem and design the computing requirements appropriate to its solution.	**P**	**C**	**C**	**C**
3	Implement and evaluate a computer-based system, process, component, or program to meet objectives.	**P**	**C**	**C**	**C**
4	Discuss the impact of computing on individuals, organizations, and society, including ethical, legal, security, and global policy issues.	**C**	**P**	**P**	**P**
5	Use current techniques, skills, and tools necessary for computing practice that supports the recognized need for continual professional development.	**C**	**P**	**C**	**C**
6	Apply design and development principles in the construction of software systems.	**P**	**C**	**C**	**C**
7	Function effectively on teams to accomplish a common goal.	**P**	**P**	**P**	**P**

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8	Demonstrate written and oral communication skills expected of a computer science professional.	**P**	**C**	**P**	**P**

P=Primary Contributor of the Student Outcome to the PEO C = Contributor

Table 2– Mapping of Student Outcomes to PEOs

Discussion of impacts, as stated at the beginning of SO #4, requires active communication with others; discussion is not done alone. Students in the program often participate in these discussions as members of small groups, which improves their abilities both as effective communicators and as team members. For these reasons, SO #4 is a primary contributor to PEO #3.

SO #4 also contributes to PEO #1 and is a primary contributor to PEO #2. Focusing on just one part of SO #4, the need for security is important to nearly all career paths graduates may take. Secure computing systems are critical to society as a whole. Loss of confidence in system security could cripple online sales and harm the economy. Ethical and legal principles must be used in designing, developing and implementing policies regarding use of information generated by and maintained in computer systems[9]. Graduates of the BS Computer Science program must use these ethical and legal principles in their daily work or in their pursuit of graduate degrees; as a result, SO #4 is a contributor to PEO #1.

New ideas or developments in society and new capabilities in computing are often intertwined with legal and ethical issues. New technologies may make old approaches to security obsolete. The definition of what is ethical may change over time. It is critical that graduates keep current with the evolving world of computing so that they can apply new ideas and computing technologies to their work in legal, ethical and secure ways, and they learn how to do this through the coursework related to SO #4. As a result, SO #4 is also a primary contributor to PEO #2.

SO #5 recognizes that the techniques, skills and tools that students have at graduation are going to evolve and change as new ideas and technologies emerge in the field of computing. This is directly related to PEO #2. Some skills may become obsolete. Some techniques may need to be tuned or even changed significantly. Continuing professional development is important for keeping skills current and graduates employable or successful in graduate studies. SO #5 is a contributor to PEO #1. It is also a contributor to PEO #4. Keeping abreast of developments is critical to remaining an active contributor in any field. Examples abound of companies that were leaders in their industry but are no longer in business as a result of failure to keep up with developments. Failure to keep up leads to individuals no longer being able to be active contributors, which ultimately results in their companies becoming irrelevant. Many developments in the field of computing involve team efforts. A significant part of continued professional development must take place with others. Therefore, SO #5 is also a contributor to PEO #3.

SO #6 falls logically between SO #2 and SO #3 as students learn to turn designs into something real. Software is developed; hardware may be developed. Time to develop various pieces and components is allocated, and designs become working systems, processes, components or programs that meet the objectives of the design and solve the problem. The ability to do this is a primary contribution to graduates being engaged and active as practicing, responsible professionals or graduate students, as discussed in PEO #1.

As graduates grow in their ability to turn designs into working solutions, they also grow in their ability to recognize how new ideas and technologies can be used to improve the systems they have built. This better equips them for participating in the continuing education opportunities of PEO #2. A new algorithm, a new programming language, or a new concept they learn may be applicable to what they are already working on. Or recognizing an opportunity or a need, they may, themselves, develop a new idea or even a new technology that has wide applicability to the computing industry. As a result, they become active

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contributors to the community and their profession, as described by PEO #4. The process of turning designs into something real involves extensive effective communication and is almost always done by teams working together; SO #6 also contributes to PEO #3.

SO #7 states that students will be able to work on teams when they graduate. For a team to accomplish its goal, the members of the team must be effective communicators. SO #7 is a primary contributor to PEO #3. Most computer development work in the computing industry is done by teams. There is normally far too much work for one person to design, develop and then implement an entire system. The ability to function effectively as a member of a team is a skill that is critical for every graduate and has a significant impact on all of the four PEO #s. This ability is imperative for PEO #1. It is very difficult to be engaged in understanding and applying new ideas and technologies in computing without interacting effectively with others. SO #6 is a primary contributor to PEO #2 as well. Finally, the phrase "active participant" implies working with others. To be an active participant, an individual must interact with others in their community and their profession in a team setting. SO #6 is also a primary contributor to PEO #4.

The written and oral communications skills described in **SO #8** are mandatory for anyone employed as a practicing, responsible professional or a graduate student. The ability to document a project, discuss alternative approaches with fellow team members, and to present progress to managers are all essential parts of being employed or pursuing graduate study. SO #8 is a primary contributor to PEO #1. These same skills contribute to PEO #2, because engagement in understanding and applying new ideas and technologies requires interacting with team members as well as other colleagues. This includes both oral interaction and the ability to interact in writing. SO #8 directly enables PEO #3. Active contribution requires strong communication skills. PEO #4 is significantly strengthened by SO #8, which enables students to develop their written and verbal communication skills.

Consistency of Student Outcomes with National University Mission

Each of the Computer Science program's Student Outcomes is also mapped to National University's Institutional Learning Objectives. This mapping closes the loop between these three major categories: PEOs, Student Outcomes and Institutional Learning Outcomes. Mapping of the eight program student outcomes to National University's seven Institutional Learning Objectives is shown in Table 3. This mapping to Institutional Learning Outcomes is critical to ensuring that each of ABET's student characteristics are enabled by the program.

The Program Review Process

National University has developed a strong culture of assessment tied to Student Outcomes, which National University refers to as Program Learning Outcomes. Several Student Outcomes are assessed in detail on an annual basis, and the ones to assess are chosen so that all program Student Outcomes are assessed over a five-year period. Each Student Outcome is mapped to individual courses in the program, identifying where the Student Outcome is introduced, where it is developed and where it is mastered. Each Student Outcome is assessed using at least two direct measures and one indirect measure. These measures are often applied to courses in which Student Outcomes are mastered, as well as to the overall program. Examples of indirect measures include surveys of graduating students and alumni surveys. Examples of direct measures include student projects and examinations. Survey results from graduates play a major role in guiding additions, deletions and revisions to objectives.

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Student Outcomes Upon successful completion of this program students will be able to:	National University Institutional Learning Outcomes 1. Apply information literacy skills necessary to support continuous, lifelong learning.	2. Communicate effectively orally and in writing, and through other appropriate modes of expression.	3. Display mastery of knowledge and skills in a discipline.	4. Demonstrate cultural and global awareness to be responsible citizens in a diverse society.	5. Demonstrate professional ethics and practice academic integrity.	6. Utilize research and critical thinking to solve problems.	7. Use collaboration and group processes to achieve a common goal.
1 Apply mathematical foundations, algorithmic principles, and computer science theory in the modeling, design and optimization of computer-based systems.	X		X		X	X	
2 Analyze a problem and design the computing requirements appropriate to its solution.	X		X			X	
3 Implement and evaluate a computer-based system, process, component, or program to meet objectives.	X		X		X	X	
4 Discuss the impact of computing on individuals, organizations, and society, including	X		X	X	X		

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ethical, legal, security, and global policy issues.							
5 Use current techniques, skills, and tools necessary for computing practice that supports the recognized need for continual professional development.	X		X		X		
6 Apply design and development principles in the construction of software systems.	X		X		X	X	
7 Function effectively on teams to accomplish a common goal.	X				X		X
8 Demonstrate written and oral communication skills expected of a computer science professional.	X	X			X		

Table 3 – Student Outcome to Institutional Learning Outcome Mapping

Gaps in the program are identified using the direct and indirect measures. These gaps are summarized in the annual assessment reviews, which are then used to bring about changes to courses and to the curriculum as part of the continuous improvement process.

The results of the annual assessments are shared with two sets of stakeholders: the program faculty and the Program Advisory Board, each of which may then suggest further changes to the program. Input from industry advisors, through the Program Advisory Board, is particularly important in ensuring that Program Educational Objectives are current. Program Annual Reviews are presented every two to three years to the Program Advisory Board, and Five-Year Program Review findings and recommendations are discussed with the Program Advisory Board with a focus on ensuring the Program Educational Objectives remain current. Program Annual Reviews and Five-Year Program Reviews are also reviewed by department chairs, deans, the National University Undergraduate Council, and the Provost.

The set of annual assessments over a five-year period provide input into the Five-Year Review of each program at National University. This in-depth review examines the annual reviews and changes made to the program as a result of findings from the annual reviews. A Five-Year

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Review Committee, ideally with representation from each of the stakeholders, carries out this examination over six to nine months and prepares comments and recommendations, including modifications, if any, to the Program Educational Objectives. This is then submitted to one or two independent external experts not associated with National University for their review and recommendations. When there are two external experts, one will be from academia and one will be from industry. Otherwise, the independent external expert is chosen from academia.

The most likely time for changes to occur to Program Educational Objectives is as a result of a Five-Year Review of the program. The recommendations of the review committee, along with the recommendations of the external expert or experts are combined into a formal memorandum of agreement that is reviewed by the Undergraduate Council for the BS in Computer Science, and then signed by the program lead faculty, the dean and the provost. The memorandum contains any significant changes and agreement on funding required to implement the changes. This overall Program Review process is summarized in Figure 1.

Conclusions

In order to describe how the BSCS Program Educational Objectives are consistent with the National University mission, a mapping was developed between the PEOs and the Institutional Learning Outcomes. To describe how the Student Outcomes prepare graduates to attain the Program Educational Objectives, a mapping between the four PEOs and the eight formal Student Outcomes for the BSCS program was described and discussed. Mapping of Student Outcomes to the National University Institutional Learning Outcomes closes the loop between ILOs, PEOs and SOs. In addition to discussion of the mappings, the overall process for review of all aspects of the program, including Program Educational Objectives, has been described.

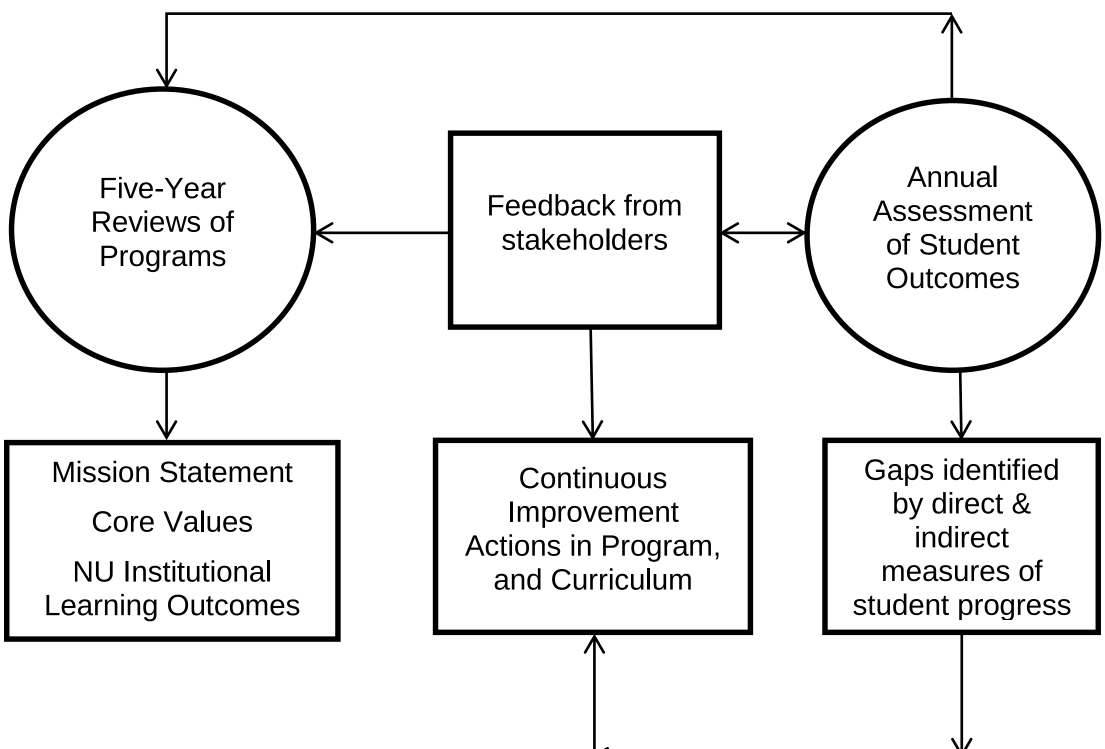

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Fig. 1 — National University Program Review Process

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Course Supplement Tools for Enhancing Students' Learning in ECE Freshmen Courses

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Abstract

All freshmen students in our Electrical and Computer engineering take (1) Introductory Circuit Analysis and (2) Introduction to C++ Programming for Engineers. These courses are the gateway courses to both Electrical and Computer Engineering programs. They not only provide the essential problem solving skills and foundation that is needed for the two majors, but also have a great impact on retention for later engineering courses. Research indicates that students often get overwhelmed by these two classes and change his/her major. The goal of this paper is to describe a set of course supplement tools that we have used in these classes to improve the students' learning and retention. Our freshmen programming class is usually populated with bimodal group of students- *some with exceptional programming background while others are totally inexperienced in this area*. In order to best utilize the class time and to make both groups of students happy a flipped mode type of instruction is used. Of which when providing students with additional materials, they could timely access before and after class lectures. These information includes PowerPoint slides, review questions, and video clips. For circuit classes there are some simulation tools that would help students to create, visualize, and understand a circuit and its sensitivity to circuit parameters. All of these supplement information are accessible from laptops, tablets, and smartphones at no additional cost to the students. Through surveys, student class presentations, and student interviews it showed evidence that these supplements have enhanced the students' interest in course materials, problem solving skills, and retention.

Introduction

Students in Electrical and Computer Engineering (ECE) receive instruction in both lecture and laboratory settings. Laboratory exercises offer students an immersive experience which are specifically designed to encourage problem solving skills in a real-world environment. We notice that many of our freshmen students are unprepared for basic courses in circuits and C++ programming. Consequently, they are very frustrated in this kind of setting and thus this situation pushes them to change their majors. We also observed that our students are very much motivated

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by practical examples and greatly benefited by lab sessions. This paper presents some of the remedial steps that we have taken in order to increase the retention in both classes.

Problems with introductory circuit analysis and C++ programming classes

Student success in electrical engineering is built on mastery of foundational circuit analysis concepts such as Kirchhoff's laws nodal analysis, Thevenin, and Norton equivalent circuits. However, the course in which these concepts are taught, comes very early in the student's baccalaureate career. Many students at this level have not yet developed sufficient skills such as effective note taking, building conceptual frameworks that integrate new ideas with existing knowledge, and the need to utilize concepts from prerequisite courses.

In our programming classes, two groups of students are encountered- the first group of student those who knows how to write code, and the second group where a student has no background whatsoever of programming. When these two groups are put together in a single class session, the second group students are very much overwhelmed and thus frustrated. Such a situation also poses a great challenge to an instructor with respect to course structuring. In other words, it is very difficult to satisfy this bi-modal student group. Also, the problems solved in a programming class is totally different from which is being used in a traditional courses. In a programming class students must understand basic structures such as loops and functions. Through our observation many students are unable to understand either of these concepts. Further, the first step in solving a programming problem is to conceive a solution and break this solution into a set of smaller sub-problems. Afterwards the student then codes each sub-problem and finally integrate these sub-problems together in order to obtain the final solution to the original problem. Many of our students are confused with respect to this form of problem solving (via making logical decisions).

Our approach

Because of modern technology almost all students have access to a Wi-Fi device such as a tablet, or a smartphone. Also, Wi-Fi connectivity is available for free in common areas such as student center, library and campus coffee shops where students work on their problems. This prompted us to search for a set of web based tools that could supplement traditional materials such as lecture notes and homework problem sets. At this point, we set a goal that the chosen web tools should be of low cost, and it should be accessible from anywhere at any time.

Circuit Course Supplements

Online web tools have been created in the HTML5 format because it is compatible with many different platforms and web browsers. Each example and problem are available in HTML and

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PDF formats. At the end of some solutions, we provide a link to watch the solution on YouTube and to simulate the circuit with online circuit simulation tool. The online resources includes a powerful schematic editor equipped also with simulation tools which has a user-friendly interface, making it easily accessible to an aspiring engineering student.

A video solution for each example and practice problems is currently available from a link sending the user to YouTube. We intentionally kept each videos five minutes and less to encourage students to watch the entire presentation. The video presentation is made by a faculty member who taught the course for many times. This kind of environment makes a student feel that the professor is guiding the students to solve the problem for them personally. Our survey has indicated that this is the most popular element in our toolkit. In the fall 2014 the National Instrument's myDAQ device has been introduced for the first time. The exit survey has indicated that students enjoyed using this device and they also prefer to use this device in the other courses. Also, by including the National Instrument's myDAQ measurement and instrumentation device to Introductory Circuit Analysis lab in Fall 2014 our survey results given at the end of the quarter shows that the students enjoyed using it and also prefer to using this device in the future courses.

Programming Course Supplements

We used blackboard in order to house lecture notes, videos, review questions, quizzes and homework and lab exercises. It has the ability to contain links to video lectures in the YouTube. These lectures are also five to ten minutes long and is given by programming professionals. They are free and can be accessed from anywhere as they are public domain.

During lab sessions students have to work on practical problem for around three hours (some of which as a group), of which are supervised by graduated students. Student are also encouraged to work on a final group project of which the size is limited to two or three students. The students may choose instructor defined projects or may work on their own project which are approved by the lab instructor. Students are required to present the project in the final week of the quarter (before finals) to their peers and they are graded by their peers and the instructor(s).

At the end of the academic year, we expect to finish the following additional supplemental items:

a. A customized website that provides introduction to any topics in the C++ environment with many examples to support the chosen topic.
b. An online tool that will allow students to debug, run, and study the behavior of their codes. This tool will accomplish the goal by accessing a C++ compiler on a remote server or Chromebook.

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Performance Assessment and Students' Feedback

In Fall of 2014, exactly 136 students took "C++ Programming for Engineers" classes in five different sections. Two sections of the classes were taught using the new design supplemental tools. At the end of the quarter a survey was given in these two sections to obtain student feedback. The following questions were asked in the both sections:

1. This class made you interested in programming
2. The PowerPoints are appropriate and helped me understand the subject
3. YouTube examples are helpful to understand the concepts
4. The review sessions were helpful in understanding the materials
5. The lab and lecture complemented each other
6. The quizzes were reasonable in the sense it tested me how well I understood the class materials
7. The online resources presented improved my learning of C++ Programming for Engineers materials and be a helpful reference for future courses.
8. Which topics are difficult to understand and needs more help?
9. What topic did you find most frustrating?
10. Any suggestions for improvement.
11. Would you prefer to take the class without the lab?

Answers for questions 1 through 7, fall into one of the five groups **SD** = Strongly Disagree; **D** = Disagree; **N** = Neutral; **A** = Agree; **SA** = Strongly Agree.

The survey results are summarized in Fig.1. It shows that 76 % students a strongly agree that YouTube examples are helpful to understand the concepts. Also, 90% students agree or strongly agree that these class sections made students interested in programming

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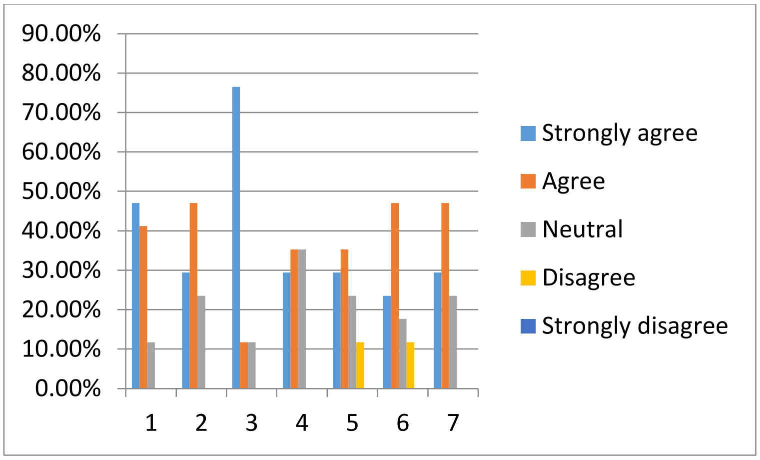

Fig.1: The survey result in C++ Programming for Engineers courses

Most students found that arrays, pointers, and recursion are the hardest areas to learn. By student's suggestions, we need more examples, practice programming exercises, and quizzes to be given on a weekly basis (after the topic covered in the class). Also, 85% of students prefer to take the class with a lab. Labs provide the much needed practice to learn and thus helped many students understand the material better.

The grade distribution is given in Fig. 2. There is a small improvement in lower graders. 6.3% of students received less than C- in the non-design sections and 3.8% students received less than C- in course redesign sections. The distribution doesn't show too much the grades improvement in higher grades. The following reasons may be attributed to this trend:

a. Redesigned class met once a week for three hours. Students were not in favor of such long lecture sessions.
b. Non-redesigned sections are primarily taught by part-timers. Part-timer professors are very lenient when it comes to grading.

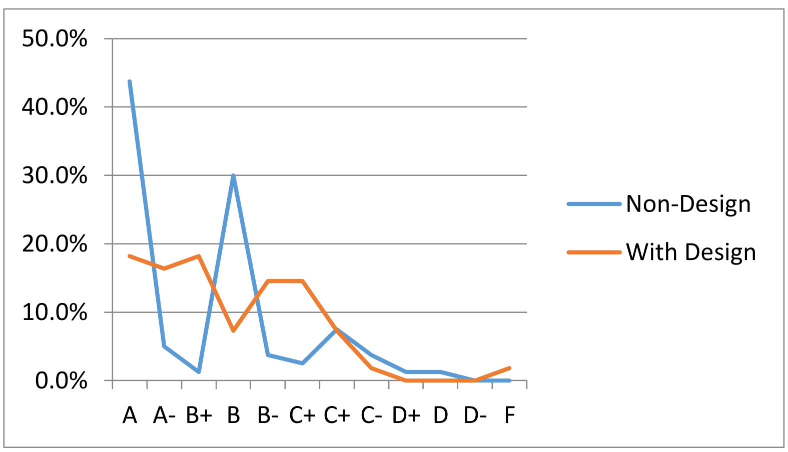

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Fig.2 : C++ Programming for Engineers courses grade distribution in fall 2014

We offered five sections of our Basic Circuit Analysis class, the ECE 109 use course redesign supplements. One section used the course redesign supplements with 35 students. The grade distribution is given in Fig.3. There is a big improvement in grades lower side of the grade spectrum. In the non-redesigned section 20% of the students have received less than C. On the other hand, only 3% of the students of the redesigned section have received less than C.

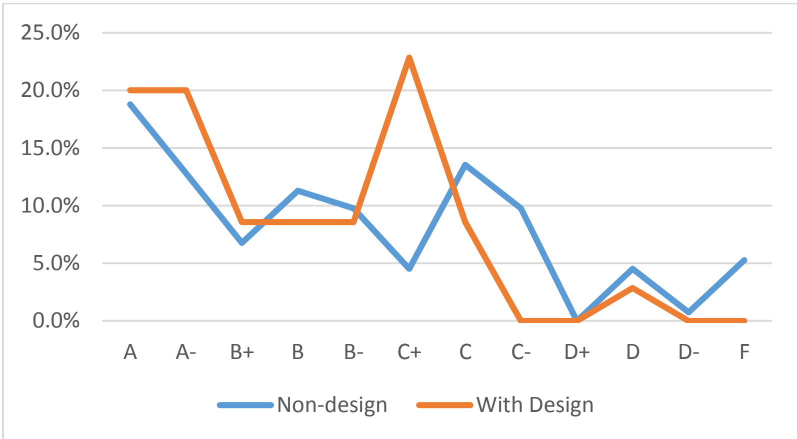

Fig.3: Introductory Circuit Analysis grade distribution in Fall 2014

Conclusion

In this paper, a set of supplements for improving students' performance in introductory circuit analysis and C++ programming are presented. These supplements include blackboard, video lectures, online circuit analysis applications and online applications that allow a student to debug and run their C++ code. All of these tools are freely accessible and these tools pose no restrictions on a student regarding location. Our surveys indicated that students in programming classes prefer short lecture sessions and long lab sessions. Specifically, they are strongly in favor of a terminal group programming project and presenting the results to their peers. In introduction to circuit analysis classes students want to see more examples on difficult topics and many practice problems and automated question bank that will test a student's understanding of the materials.

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Experimentation with flipped classroom paradigm in freshman level Biomedical Engineering course – comparison with advanced undergraduate course

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Abstract:

The flipped classroom approach replaces delivery of learning content with active forms of learning in the classroom, while content delivery usually occurs through pre-recorded video lectures. We examined whether the flipped classroom approach leads to improvement in student performance in a freshman level "Introduction to Biomedical Engineering" course and a junior-senior level "Medical Electronics" course. Similar approaches were used for both courses, with video lectures assigned for viewing ahead of classroom meetings in which the students worked on problem-solving worksheets with assistance from the instructor and a teaching assistant. Student performance was assessed by comparison of scores on exam questions that had been previously assigned to matching student cohorts taught with a traditional lecture approach. Students were also surveyed for feedback about their perceptions of the flipped classroom. We found that students performed at a higher level for the more advanced course while performance was lower for the introductory course. Student feedback revealed a higher degree of satisfaction in the junior-senior level course. Both groups perceived that the flipped classroom approach promoted placing the responsibility of learning on the students. We speculate that different levels of preparation for college were in part responsible for the mixed reception of the flipped classroom approach among the freshmen.

1. Background:

The flipped classroom approach inverts the traditional "teaching/lecture – learning/homework" model by presenting the course content outside of classroom ahead of the traditional lecture period and by replacing the lectures with active forms of learning in the classroom [1] [2]. Typically, the content is delivered online through recorded lecture videos complemented by textbook and literature reading, browsing websites, and other modes of content delivery [2]. Reported advantages of the flipped classroom approach include making the students responsible for their learning and helping them develop lifelong learning skills [3] as well as providing them with individualized instruction to remedy weaknesses or misconceptions [4]. Time not spent listening to the lectures is freed to work on additional and more complex applications of the course content, including open-ended design exercises [1]. Students work in the classroom in groups and this form of cooperative learning is thought to reinforce their understanding of the course material [2].

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Several studies have reported measureable improvements in exam scores and problem solving skills with the flipped classroom [5] [1]. Other studies found non-significant differences between lecture cohorts and flipped classroom cohorts [2]. Students' perceptions of the flipped classroom approach have usually been favorable, but with consistent numbers of students indicating a preference for the traditional lecture format [6]. There are questions as to whether the flipped classroom approach can be applied equally well in college classes for less experienced underclassmen and more advanced upperclassmen [1].

We adopted the flipped classroom approach in a freshman-level Introductory course and a more advanced medical electronics course of our Biomedical Engineering program and measured students' performance on exams as well as students' perceptions. The data was analyzed to compare and contrast performance and students' feedback with the flipped classroom approach for student cohorts at different stages of their college training.

2. Methods

The flipped classroom model was implemented in two one-semester courses of the undergraduate biomedical engineering curriculum. The first course was a "Medical Electronics" course that is required within the curriculum and is attended in the Spring semester by juniors and seniors within our program. Based on the experience gained in this first course, the flipped classroom was applied the following semester to "Introduction to Biomedical Engineering", a freshman-level course offered in the Fall semester to incoming freshmen.

2.1. Course Format

"Introduction to Biomedical Engineering" is an algebra-based course that introduces conservation principles applied to living and man-made systems. In one semester, students learn primarily about conservation of mass and conservation of charge. The students are exposed to the connections between the subjects they learn in basic science courses (chemistry, physics) and engineering applications relevant to Biomedical Engineering. "Medical Electronics" discusses the analysis and design of analog electronic functions commonly found in measurement systems and medical instruments and the devices used to implement these functions in hardware. In particular, students learn about medical transducers and transducer amplifiers, DC power generation and linear power supplies, signal amplification with bipolar junction transistors and analog amplifiers, and analog filters. Table 1 below highlights similarities and differences between the two courses as they were taught with the flipped classroom approach.

	Introduction to BME	**Medical Electronics**
Number of students	116 in two sections with separate instructors	47 in one section
Student level	First-semester freshmen	Juniors and seniors
Mode of delivery	Video lessons on LMS	Video lessons on LMS
Sample problems in videos	Yes	Yes
Preparatory activities	"Learning checks" scored for effort	Group quizzes at the beginning of class

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In-class activities	Problem-solving exercises, approximately 50% from textbook, 50% instructor-generated	Circuit analysis/design exercises, all instructor-generated
Activities format	Group work	Group work
Homework	Yes – textbook and instructor problems	Yes – textbook and instructor problems
Assessment mode	Quizzes (6) + Midterm (1) + Final exam	Quizzes (8) + Midterm (1) + Final exam
Assessment format	Multiple-choice problem-solving questions and short-answer problems	Multiple-choice problem-solving questions

Table 1: Format of the two courses

As table 1 illustrates, the implementation was fairly similar between the two courses. The "Introduction to BME" course was divided in two sections to accommodate the number of registered students and both sections had approximately the same number of students. One of the two instructors for this course was also the instructor for the "Medical Electronics" course while the other instructor taught the Introductory course for the first time. The two sections proceeded at the same pace with tight coordination between the two instructors. The same assignments and exams were used for the two sections.

For both courses, the instructors prepared Powerpoint presentations of course content, which were narrated and presented in video format using Camtasia Studio (Techsmith). The Powerpoint presentations included sample problems, of which about half were followed by a detailed presentation of the solution while the other half were left for the students to solve on their own. Both the video lessons and the Powerpoint presentations were posted on the learning management system Blackboard.

Students in the "Introduction to BME" course completed "Learning checks" comprising a few exercises and conceptual questions to test their understanding of the video lessons they had watched. The learning checks motivated the students to watch the lessons and allowed the instructors to spot misunderstandings in the content presented in the video lessons. Seven learning checks were used in the semester, approximately one every other week. Most students completed the learning checks even though these were not scored and not counted in the course grade. In the "Medical Electronics" course, group quizzes were used instead. The group quizzes also comprised conceptual questions and problem-solving exercises but they were solved by the students in groups of 3 to 6 students, with each group completing one response sheet. After the allotted time expired, the groups exchanged their response sheets for scoring. The questions were discussed with the whole class and the student groups marked the answers on the response sheets. The group or groups with the highest number of correct answers were declared "the winners" and received a token prize, usually a bonus point on the next individual quiz. While not having the same level of accountability as the "Learning checks" in the Introductory course, the group quizzes in the advanced course resulted in playful challenges between student groups.

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Classroom time was spent solving problems in groups for both classes with the instructor and one teaching assistant roaming among the groups and guiding them toward the solution when necessary. When an interesting point, a misunderstanding, or an original solution was identified with one group that warranted mention to the whole class, the instructor discussed it with all the students before resuming the problem-solving exercises. For each problem, the solution was discussed either briefly or in detail after the groups had been able to complete or approach the solution. For the "Introduction to BME" course, the problems originated either from the textbook or were prepared by the instructors while for the "Medical Electronics" course, the instructor generated nearly all the problems as the students tended to not carry their textbook to class.

Traditional homework was assigned in both courses after the course material had been presented through the video lessons and discussed in class through the activities. The amount of homework was approximately 40% that assigned in previous years when traditional lecture format was used (~2 problems/week vs. 5 problems/week)

2.2. Assessment of flipped classroom approach

Three instruments were used to measure the effect of the flipped classroom approach in comparison with the traditional lecture approach: 1) quantitative comparison of performance on exams; 2) a student survey with questions on the student experience; 3) end-of-semester course evaluations.

2.2.1. Comparison of performance on exams

Student learning and problem solving ability on course-related topics measured by scores on exam questions was compared for the flipped classroom year and the preceding traditional lecture years.

For the Introductory course, the final exam included 7 multiple-choice problem-solving questions (out of a total of 13) and 2 short-answer problems (out of a total of 3) that had been used in the previous offering of the course with the lecture format. Because the point value assigned to the multiple choice questions was slightly different in the two offerings of the course, the marks obtained by each student on these 7 questions and 2 problems was added and scaled to a maximum score of 20. For the electronics course, the final exam included 20 multiple-choice problem-solving questions (out of a total of 32) that had been used on the final exams for two preceding offerings of the course with the traditional lecture format. The marks on these questions were added resulting in a total score out of 20.

For both courses, the exam scores were compared for the flipped classroom offering and the traditional lecture offerings using an unpaired t-test to examine if there was a significant difference in performance between the 2 instructional approaches. The exam scores were regrouped in categories corresponding approximately to the A, B, C, D ratings (A: 18-20, B: 15-17, C: 12-14, D: < 12). Two-way contingency analysis and a χ^2 test were used to examine if the score distributions were different. All analyses were carried out with SPSS (14.0).

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2.2.2. Course survey

An instructor-generated anonymous survey was administered electronically to the students a few weeks before the end of the semester during the flipped classroom year to gather feedback about various aspects of the course, including the video lessons, the in-class activities, and the assessment approach. In addition to ratings, comment fields were included for several survey questions. The survey of the Introductory course was an updated version of the survey used for the electronics course with a few additional questions.

2.2.3. End-of-semester course evaluations

For both courses, students completed end-of-semester course evaluations mandated by the University. All the questions were answered on a 1-5 Likert scale with 5 being highest. In addition to two global evaluation questions ("Overall, how would you rate this instructor?" and "Overall, how would you rate this course?"), the students rated the course and the instructor on 10 focused aspects of their experience. The student response rate to these surveys was approximately 60-70%.

The student responses obtained for the flipped classroom offering of the courses were compared to the responses obtained during the 6 previous years when the traditional lecture + discussion format was used using a one sample t-test. Only the ratings of the instructor who had taught the two courses were used since the other instructor had not taught the Introductory course in the lecture format.

3. Results

3.1. Exam performance

3.1.1. Overall scores

For the Introductory course, the final exam scores of 116 students (both sections) from the flipped classroom year were compared to the scores of 47 students from one of the sections of the preceding traditional lecture year. For the Electronics course, the final exam scores of 47 students from the flipped classroom year were compared to the scores of 87 students from the two previous lecture years. For the Introductory course, the average final score in the flipped classroom year was below that observed in the lecture year (Table 2). The converse was observed for the electronics course, for which the final score in the flipped classroom year was markedly higher than that observed when the course was offered in the traditional lecture format.

Course	Flipped	Traditional	t-stat	P value
Introductory	16.6±2.6	18.1±1.7	3.7	< 0.001
Electronics	16.1±3.5	14.4±3.5	2.7	0.007

Table 2: final exam scores for the two courses and the two instructional methods

3.1.2. Distribution of scores

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Figure 1 shows the distributions of exam scores for the two courses and two instructional approaches. For the Introductory course, the distributions of exam scores were negatively skewed for both years with a higher frequency of scores in the 18-20 range in the traditional lecture year. The distribution of scores was also negatively skewed in the electronics course for the flipped classroom year. However, the exam scores for the traditional lecture version of the electronics course were more evenly distributed over the whole range. For both courses, contingency analysis revealed significant differences between scores distributions in the traditional lecture year and in the flipped classroom year ($p < 0.02$). There were no differences in the average scores or score distributions for the two sections of the Introductory course, which ruled out a possible instructor effect on the students' performance.

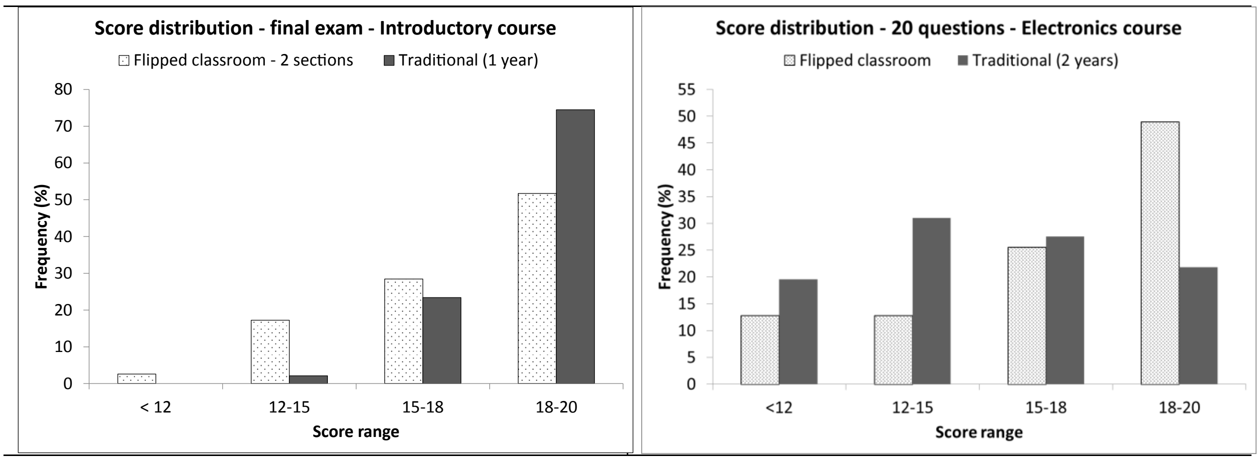

Figure 1: distribution of scores on the final exams of the two courses

3.2. Student Survey

The response rates to the student survey were comparable for the two courses: 50 out of 116 for the Introductory course and 25 out of 47 for the Medical Electronics course. Responses to some of the questions are summarized in table 3 below.

Question	Intro to BME	Med. Electronics
Video lesson questions		
What percentage of video lessons have you watched?	77%	77%
Did you find the videos clear?	Yes: 80%	Yes: 100%
Did the videos help you learn the class material?	Yes: 72%	Yes: 96%
Preparation quiz questions		
What percentage of learning checks did you complete?	95%	NA
Would you prefer if a learning check for every lesson?	Yes: 43%	NA
Did you find the group quizzes useful	NA	Yes: 67%
In-class activities questions		
Did you find the class activities helpful to complement readings and video lessons?	Yes: 60%	NA
Did you enjoy the activities as implemented or would you prefer a more structured classroom?	As is: 18%	NA

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Was there another type of in-class activity you would have liked?	Yes: 49%	Yes: 25%
Did you find it effective to have the instructor and teaching assistant work with individual student groups?	Yes: 72%	NA
Optimal amount of time to spend on each activity?	NA	11-20 min: 58%
Homework questions		
Did the homework help you synthesize your learning?	Yes: 84%	Yes: 96%
Was the amount of homework appropriate?	Yes: 74%	Yes: 88%

Table 3: Responses to student survey. NA indicates the question was not in the survey

The video lessons were well received by the two groups of students who reported watching most of them. Students from the Introductory course reported completing 95% of the learning checks which was confirmed by the actual number of samples collected in the semester.

Sixty percent of these students found the in-class activities helpful and commented that the activities helped clarify the videos and deepen their understanding of the topics. However, about half of Introductory course students reported they would have preferred a different type of activity, while this was the case only for 25% of the students in the Electronics course. A large number of students in the Introductory course indicated they would have preferred more lecturing or a short lecture before the activities. Both groups of students found the traditional homework useful.

In their free comments, some students in the Introductory course indicated that the course was challenging and presented many aspects of the sciences and fundamental aspects of BME while others reported the material was elementary or too easy. The ability to focus in the flipped classroom setting which is noisier because of the conversations between groups was quoted by several students as a distraction. This complaint was never mentioned by the students of the Medical electronics course where the noise level due to multiple conversations was qualitatively similar.

3.3. Course evaluation

The student ratings in the end-of semester course evaluation are traditionally lower for the freshman-level Introduction to Biomedical Engineering course than the ratings observed in other courses. In part, the freshmen begin college with different expectations about what biomedical engineering is. In addition, they have a limited basis for comparison between college courses. This was also the case for the 2014 flipped classroom year. In particular, student responses to the overall instructor ratings were not different from those observed when the course was offered in the traditional lecture mode (Fig. 2). For the Medical Electronics course, the overall instructor rating was significantly higher with the flipped classroom. For both courses, the overall course rating remained in the range observed with the lecture mode (Introductory course: 3.2 in flipped classroom year vs. 3.3±0.1 for lecture years; Electronics course: 4.3 in flipped classroom year vs. 4.1±0.3 for lecture years).

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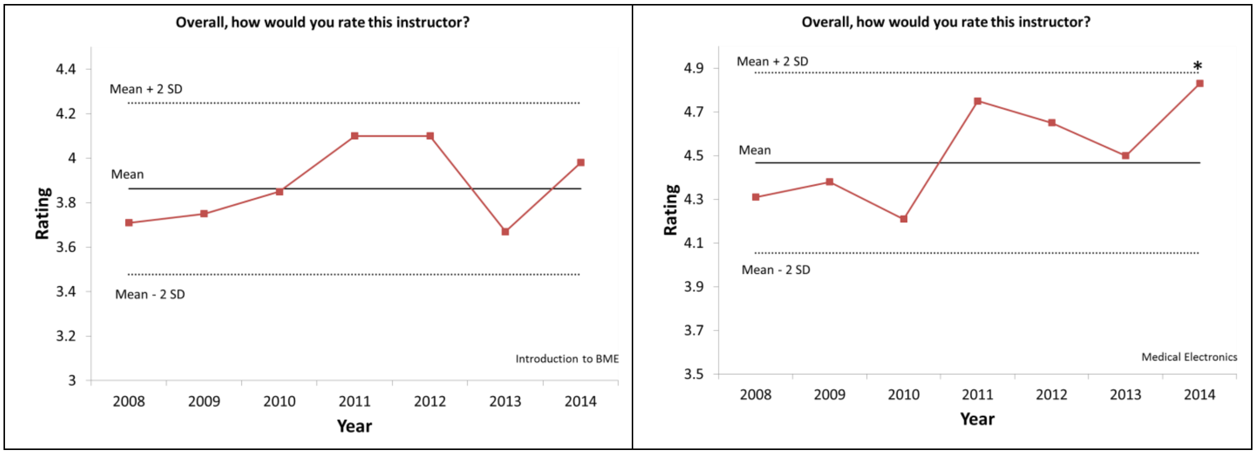

Figure 2: Ratings in flipped classroom year (2014) and 6 preceding lecture years in response to evaluation question: "How would you rate this instructor?". Left: introductory course; right: Electronics course

In general, the student ratings on the focused questions were not significantly different for the flipped classroom year in the Introductory course while the ratings were increased in the electronics course suggesting more enthusiasm for the flipped classroom in the electronics course.

Two questions showed a significant upward jump for both courses in the 2014 flipped classroom year. Students' responses to the question "The instructor encouraged students to participate in their own learning" were significantly higher (Fig. 3). In fact, the magnitude of the change was larger for the Introductory course and indicated a substantial difference compared to the year-to-year fluctuations observed in the lecture years. Likewise, the responses to the question "The instructor was enthusiastic about communicating the subject matter" were increased compared to the year-to-year average for both courses (Fig. 4).

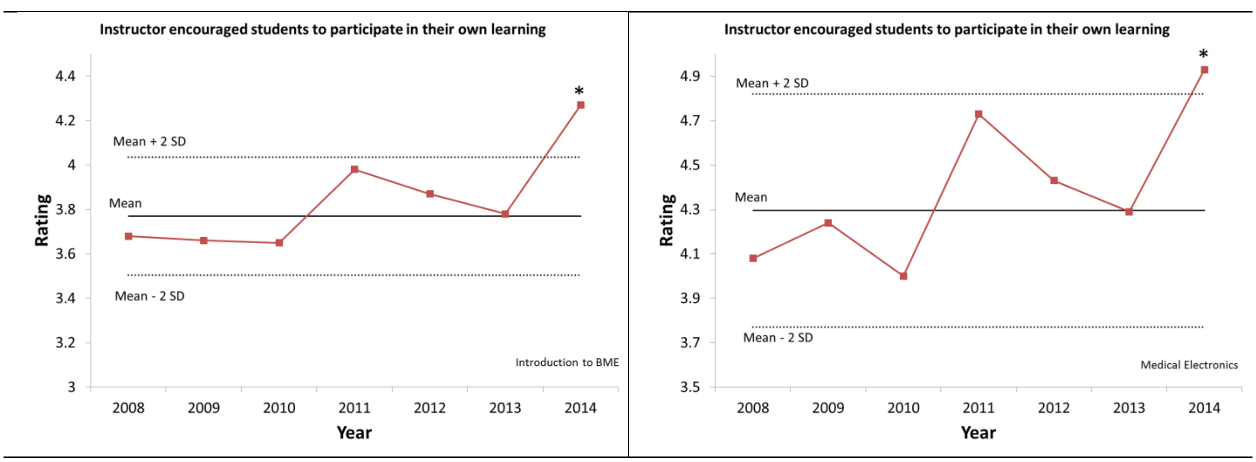

Figure 3: Ratings in flipped classroom year (2014) and 6 preceding lecture years in response to evaluation statement: "The instructor encouraged students to participate in their own learning?" Left: introductory course; right: Electronics course

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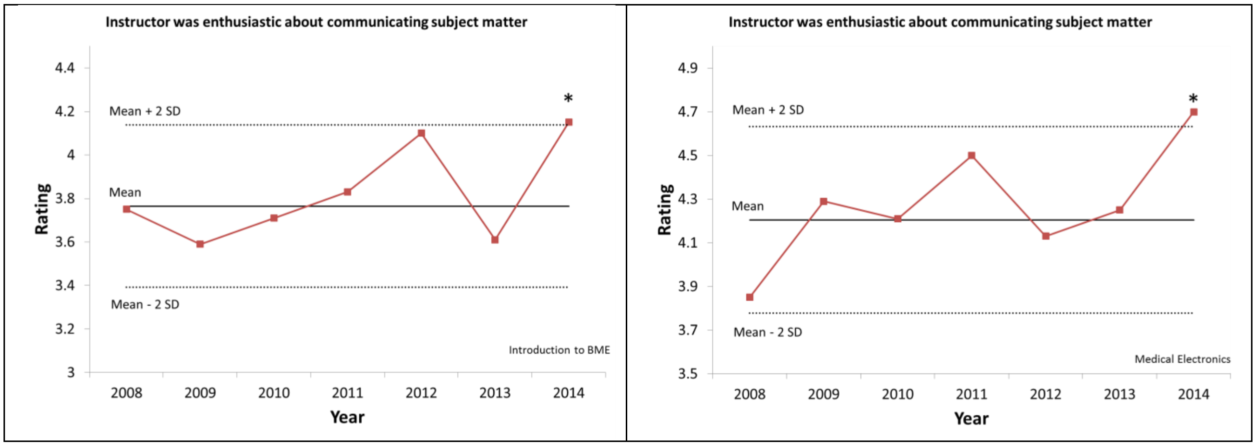

Figure 4: Ratings in flipped classroom year (2014) and 6 preceding lecture years in response to evaluation statement: "The instructor was enthusiastic about communicating the subject matter?" Left: introductory course; right: Electronics course

In their free-response comments, nearly half of the respondents indicated they would have preferred a more traditional lecture approach for the Introductory course, whereas this occurred only a few times for the medical electronics course. These results are in agreement with the responses noted in the student survey.

4. Discussion

The results of this study may be surprising in that a similar implementation of the flipped classroom model in two courses was better accepted by the juniors and seniors in the Medical Electronics course than it was by the first-semester freshmen in the Introduction to Biomedical Engineering course. Exam performance improved markedly for the Electronics course while it declined for the Introductory course when compared to performance in a conventional lecture classroom. Yet both student cohorts reported watching the video lectures to the same extent and found equivalent amounts of homework equally helpful to solidify their understanding of the course content.

Comparison of objective student performance in a flipped classroom and a traditional lecture setting has been reported in a small number of studies of undergraduate engineering and science cohorts for semester-long interventions [5] [2]. In a senior-level course on user-interface design taught concurrently to 2 sections with the flipped classroom and the traditional approach, exam scores were found to be marginally higher and overall performance on assignments was significantly higher for the flipped classroom group [5]. A study of a senior-level mechanical engineering course structured like our study over two consecutive years also revealed better exam performance for the flipped classroom cohort on certain course topics [1]. Student performance was equivalent in the two cohorts in a sophomore-level numerical methods course [2].

A near endless number of variants can be imagined for electronic circuits even for an Introductory analog electronics course dealing with a limited number of devices and functions. Thus the ability to analyze new circuits becomes essential to succeed at problem-solving even for

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closed set exam problems. Learning a few standard solutions by watching the instructor solve a small number of problems and through a limited amount of homework practice in a traditional lecture format may be insufficient to learn to analyze circuits not seen before. Practicing circuit analysis and problem solving intensely for one semester would have provided the flipped classroom students with enough practice to solve many more circuit problems related to the course content. This could explain the higher scores in the flipped Electronics course compared to the lecture version and a final exam distribution of scores skewed toward the "A" grade in the flipped classroom and more evenly distributed over the "A – D" range for the conventional lecture format.

In contrast, for the Introductory course, the set of possible exam problems and questions was more limited and many exam questions, which by nature of the study design originated from the lecture offering of the course, would have resembled problems first solved in class and then revisited in homework by the "lecture" cohort. Thus, the "lecture" students were prepared to solve these problems and performed at a very high level on their exams (>70% in "A" range). More problems were attempted and covered in the flipped classroom setting, but this abundance of problems could have created confusion among some students when preparing for the final exam and led to lower exam scores. Thus, a limitation of the study design (comparison of performance on exam questions from the lecture offering) coupled with the nature of the course content could explain the observed performance differences between the two courses.

The flipped classroom approach transfers the responsibility of learning the course content away from the instructor and toward the students while helping them practice the skill to learn on their own [3]. This feature was recognized by the students in both courses, and more acutely so in the Introductory course as indicated in the course evaluations (Fig. 3). It is possible that a substantial number of freshmen in that course were not accustomed to being in charge of their learning and as a result would have viewed the flipped classroom model to be less desirable than the lecture model. The juniors and seniors in the Electronics course, being comfortable learning on their own, would have been more willing to accept this responsibility and in this way easily adapted to the flipped classroom approach. Difficulty to adapt to the flipped classroom approach has been reported in other studies of Introductory and underclassmen courses [6] [2].

Strayer [6] analyzed the perceptions of students toward learning activities in a flipped classroom environment. The approach of some students was summarized by "I want you to show me" while others preferred to "struggle through and only ask questions when they were stuck". Interestingly, a good number of students of the Introductory course stated in their course evaluations that they would have preferred to have the instructor solve a few problems at the board before attempting the problem-solving activities with their groups. It is possible that the freshmen of the Introductory course were not ready for the looser structure of the flipped classroom, the noisier classroom environment, and the onus of having to learn the course content ahead of time. However, the flipped classroom has been very successful in high school science courses [4] with younger students than the freshmen of our study. Thus, it is more likely that inhomogeneity in prior preparation and in expectations toward teaching and learning among first-year college students coming from different high schools could have affected their perceptions of the course and of the instructional method. In such circumstances, it may be preferable to offer a brief "power" lecture at the beginning of the classroom meeting to

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homogenize the knowledge level of the students and increase the comfort level of some students who need additional guidance.

Exam performance on problem-solving multiple choice questions or closed ended problems only captures limited aspects of learning and does not capture other valuable engineering skills that map to the ABET student outcomes such as the ability to work in teams (outcome d) or the ability to engage in lifelong learning (outcome i) [3]. In as much as the flipped classroom systematically exposes students to group work for several hours every week in the classroom and trains them to learn on their own through the video lectures, the approach can help students better develop as future engineers while also helping engineering programs to satisfy accreditation requirements.

Among the limitations of the study, the comparison between conventional lecture format and flipped classroom format was done on relatively small groups of students with a single year of experience for the flipped classroom. While the instructors were used to having students work on problems in the classroom even in the lecture offering of the courses, this was their first experience with fully flipped courses.

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Comparing an Online vs. On-ground Undergraduate Engineering Courses in Dynamics

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Abstract

Now over one trillion dollars, outstanding student loan debt has ballooned by more than 400% in the past decade while credit card debt only grew 25%. State and Federal legislators' scrutiny of this significant increase in student debt has focused attention on time-to-graduation for both freshman starts and transfer students, increasing the total number of graduates and operational efficiency of undergraduate instruction. Transfer students in engineering have unique issues related to time-to-graduation since they are often missing one or two key prerequisite courses. To increase contact between students and engineering faculty, several key technical courses have moved to the sophomore year. Often, these courses serve as the key initial links for a sequence of required advanced courses, but are rarely offered at the community college level. As a result, many transfer students cannot follow the normal progression of junior level courses which puts them at high risk for taking more than 2 additional years to graduate, further increasing the debt load upon graduation. This paper describes the results of an experiment designed to help quantify one option that can be used to improve this situation for transfer students - online summer offerings of key prerequisite courses. The course selected for this experiment was *Dynamics* which is a prerequisite for many junior level classes and is not offered at most community colleges. The course was taught in a 100% online format and a separate section was taught in a traditional on-ground format in the summer of 2014. To control the experiment, both of these courses were taught at the same time by the same faculty member and all assignments were the same including the final examination. To further ensure comparability of the student's scores, online students we required to take the final exam live on campus at the same time and in the same room as the on-ground students. While the dropout rate was higher for online students, there was little other difference in course performance. The online students actually had slightly higher average scores of 61.9% on the final examination than the on ground students who averaged 60.5%. These results show promise for the use of online courses in specific situations to help provide options for schools as they continue to focus on improving the operational efficiency of teaching and reducing student loan debt.

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Introduction

In 2010, total student debt surpassed household credit card debt for the first time in US history and is now second only to mortgage debt[1]. Total student debt stood at $364 billion in 2004. Ten years later in 2014, that number has nearly tripled and now stands at an alarming $1.1 trillion. The size of the average student loan ballooned from $16K in 2004 to nearly $30K in 2014. What's causing even more concern for economists and politicians is the increase in default rate for students loans. During the great recession (2009-2012), default rates for all other forms of credit (mortgage, auto, and credit card) decreased. Student loan defaults increased during this period and now stands at over 11%, a higher default rate than any other form of credit. Some research[2] also shows an association between higher student loan balances and default rates and delays in home buying among this population, thereby influencing students to live at home for longer periods.

According to the US Department of Education (DOE)[3], nearly 5 million undergraduate students participated in distance education in the fall of 2012. For these statistics, distance education includes courses where the students are separated from the instructor and where a variety of tools and processes are used to present content and provide for student-faculty and student-student interaction. Content delivery and interaction under this definition could be either synchronous, asynchronous or both. While the majority of these students (58%) who took all of their classes online attended private, for-profit schools, increases in the number of students taking one or more online classes occurred across all college campuses (2-year, 4-year, public, private/non-profit and private/for-profit). In their 10-year study, Allen and Seaman[4]concluded that the interest in online education continues to be strong and online course development and delivery is expanding at a rate much faster than traditional lecture-based classes. According to the DOE, more than 32% of college students sampled in 2014 reported taking at least one online class. These 7.1 million students represented a 6% growth over the previous year. This growth rate, which far exceeds the growth in over-all enrollment, was still the lowest year-over-year growth since 2013. Students continue to report *Convenience* as the most compelling reason for taking an online class and *Lack of Interaction* as the reason for not taking an online course.[4]

Several studies[5,6] have shown little difference between online and on-ground courses. This was reported as far back as 1999 in Russell's *No Significant Difference*[7] comparative study of student learning in the online and traditional classroom environments. In this study students in the online versions of the courses performed better than those attending the "brick-and-mortar" classes. In Summers[8], student's exam results were higher for the online cohort but student satisfaction was higher for on-ground classes.

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A large study of over 40,000 community college students in Washington State[9] found that all students had some decrement in performance in online classes (2.77 GPA vs 2.95 for on-ground students). Interestingly, this study also showed that females consistently outperformed males and younger students, Black students and those with lower grade point averages also performed at a lower level in online courses. Other studies such as Shukla[10] and the United States (US) Department of Education[11] have had mixed results. The latter study reviewed online education specifically examining research on online versus traditional classroom teaching from 1996 to 2008. The pooled analysis in this study found that there were better learning results from a combination of online and on-ground learning components. Other factors can influence student performance in online classes. For example, in Beale[12] online courses resonated more with those who are more self-directed and able to define and follow their own schedule. Other researchers[13] have found that older students tend to do better in online courses.

There has been much less research focused on the effectiveness of online vs on-ground in the STEM disciplines. Those studies that are available do support similar, but not quite as consistently positive results. In Shukla[10] lower level math courses were delivered in on-ground (face-to-face), hybrid and 100% online formats. In all cases, completion rates were better for on-ground when compared to online with some students showing a steeper decline than others (males and students with lower prior GPAs). However, in a preparatory algebra class in this same study, the hybrid version of the class had better outcomes than the on-ground version.

While there are some studies comparing online and on-ground courses in STEM disciplines, the number of these studies is limited and often focused at the community college or at non-researched focused institutions. One of the reasons that STEM subject areas have been studied less is that there are simply fewer STEM classes offered in an online format. In one large study at the community college level, the average proportion of enrollments that were online was 10.2%. In this same study, enrollments in online STEM subjects average 3.5% while enrollments in Humanities and Social Sciences was a very strong 20% (see Table 1).

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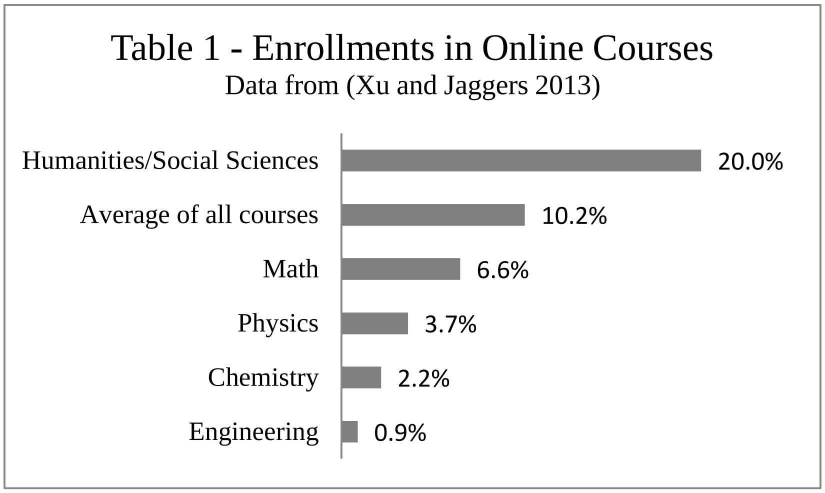

Study Design

Dynamics is a key prerequisite course for engineering majors that freshman starts usually take in their sophomore year. The normal sequence of classes in the junior year includes two quarters of fluid mechanics beginning in the fall quarter followed by a heat transfer course in the spring. The first fluid mechanics course as well as two other required courses (*Vibrations* and *Machine Design*) all require *Dynamics* as a prerequisite. Many senior level classes, *Control Systems* and *Mechanical Engineering Design*, also carry *Dynamics* as a prerequisite. Transfer students who have not taken *Dynamics* prior to the beginning of the junior year will not be able to take this normal sequence of classes which puts them a much higher risk of taking more than two additional years to complete their degrees and incurring additional student loan debt. To respond to this issue, community college transfer students are given the opportunity to take *Dynamics* in the summer quarter prior to beginning school at the university. Due to the high costs of housing and the loss of being able to earn money at a summer job, taking a summer class is only accessible to those students who are within driving distance from the school. Students out of the area or those with prior summer commitments are not able to take the on-ground version of the class.

To help solve this issue, *Dynamics* was offered in the summer of 2014 in both online and on-ground formats simultaneously. The on-ground version of the course was taught using a flipped format as discussed below. The enrollment in the online offering was kept small, as this was an experiment in determining the proper support level and supplemental materials needed to turn a fully flipped course into an online format. It was also kept small to avoid compromising the overall quality and to explore the possibility and feasibility of similar offerings in the future to enhance the ability of transfer students to complete this required class before their fall entrance.

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The flipped format was relatively mature: all lectures were divided into 7-15 minute narrated screen captures, each lecture followed by a diagnostic quiz. The low stake quizzes were populated by constructive feedback for all answers. The lectures and quizzes were used earlier in 2014 in a flipped format for a class of 100+ students. The enrollment in the flipped formatted class during the summer of 2014 was 35. The enrolment of the online class—taught by the same instructor – was expected to be in the 15-20 range, limited to those who could not attend class time, due to distance or employment, etc. (to avoid self-selection with bias toward those who seek online classes). Due to logistical issues, only 12 students registered for the class, though only 7 completed the class (a higher attrition than normal for regular summer offerings). The flipped (on-ground) class met twice a week, for 100 minutes each. During the regular academic year, this class meets twice for 75 minutes plus a 50 minute discussion session, during each week. With large enrollments, the discussion hour is offered multiple times to reduce the size, each led by a teaching assistant. Due to the relatively small size of the summer offering, less than 50, the discussion session was combined with the regular lectures. Given the nature of lecture time in the flipped format (which is closer to a discussion hour than a traditional lecture), this simply added to the instructor contact hour and thus may have reinforced the notion of `extra work' often associated with the flipped class room (extra work for students and instructor).

The key component of the flipped format is that the class time is turned into 1/3 review of the most difficult to comprehend lecture segments, 1/3 question and answer, and 1/3 setting up and breaking down of the homework assignments. While the online material was common between the two formats, the approximately 3-4 hours of contact time would be lost to on-line students.

To mitigate this deficit, the following steps were implemented:

1. All homework assignments had been solved and discussed in video segments.
2. Strong reliance on Piazza forum, where every question by students would be answered by the instructor (as opposed to the flipped version where the forum was meant for student use and only monitored by the instructor). This way, a record of `Q & A' would be available to all.
3. A `muddiest segment' poll was used to identify the difficult lecture segments, for which additional material or review segments were created, during the term
4. Video conferencing was used to accommodate one-on-one sessions (Skype, Google Hangout).

Given the size of the online class, some of these features did not provide statistically significant data. For example, the muddiest point poll were often inconclusive, as only a subset of 7 students would vote and the numbers were too small to identify one or two candidates. Similarly, efficacy of Google Hangout (with capacity of up to 10 participants in a session) to accommodate STEM discussions could not be evaluated. The combination of Skype/Google Hangout (or similar) with Piazza can provide a platform to provide personal one-on-one or few-

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on-one discussions that accommodates sharing of figures or equations. Creating real time technical posts could prove problematic without a great deal of preparation. For example, students might be required to identify the concepts or problems that they want to discuss to give the instructor the time to find the figures, equations and other related material that might be needed in creating the posts.

Students in both the online and on-ground offerings of the course were given the same homework assignments, midterm, and final exams.

Results

The mean test results for the two midterms, final exam, and final course grade for online and on-ground students in the summer offerings of the *Dynamics* course are shown in Table 2.

Table 2
Midterms, Final Exam and Final Course Scores
Mean (SD)

	Midterm 1	**Midterm 2**	**Final Exam**	**Course Final Grade**
On-ground Students (N=23)	66.1 (14.5)	58.1 (14.3)	60.5 (10.4)	66.2 (9.4)
Online Students (N=7)	65.0 (9.3)	57.3 (11.2)	61.9 (10.7)	67.7 (6.4)

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Due to the small sample size, especially for the online group where N=7, p values where greater than 0.1 for all comparisons. There is still some qualitative insight that can be gained from comparing the mean scores. The first midterm scores were slightly better for the on-ground group vs the online group (66.1% vs 65.0%). On-ground students slightly outperformed the online students on the second midterm. Online students did slightly better on the final exam than their on-ground counterparts (61.9 vs 60.5). Online students also had higher average total class scores (67.7% vs. 66.6%). The total scores included both midterms, the final exam and quiz, and homework scores.

Comparisons of the quiz and homework scores had the same confidence issues ($p > 0.1$) due to the small sample size for the online course offering. The qualitative theme is still valuable and underscores an interesting possible trend. Online students consistently outperformed on-ground students in homework scores (91.3 vs 83.0), quiz participation (95.7 vs 92.0), and quiz grades (94.7 vs 90.0).

Table 2
Quiz and Homework Grades
Mean (SD)

	Quiz Participation Grade	**Quiz Grades**	**Homework**
On-ground Students (N =23)	92.0(16.4)	90.0(16.8)	83.0(25.0)
Online Students (N=7)	95.7(9.2)	94.7(8.7)	91.3(6.4)

Conclusions

The indications from this study are in line with other research[14,5] that has found little difference between student performance (measured by homework, midterm and final exam scores) as a function of the mode of instruction (online, on-ground, flipped, etc.) Our results also indicate that online students did a measurably better job (+10%) on their homework assignments than their on-ground counterparts. Homework assignments in STEM classes tend to be a larger component of the entire course workload. In STEM courses, weekly sets of multiple homework problems are typical and key to student performance and research[15] has shown strong correlations between time spent on homework and grades. Our study had similar results – the final course grades for online students (who did measurably better on their homework) were higher that the final course grades for on-ground students.

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The option to take the *Dynamics* course online was provided to students in this study an attempt to ensure that those students who were not within driving distance to the campus would still have the opportunity to take this key prerequisite course prior to beginning their junior year. All newly accepted transfer students were made aware of this option several months before the start of the summer quarter in which both versions of the class were taught. As mentioned above and in order to ensure more randomization of the population, students were limited in their ability to "self-select" into the online group. Students were required to petition the school with a strong justification as to why they needed to take the online version of the class. Some component of the students' ability to "self-direct" could still have been a factor in their decision to try to convince the university to allow them to take the online version of the *Dynamics* course. Other research has indeed shown that students who are more self-directed tend to do better in online courses.[13] In this latter study, the researchers found that "predictors of student performance in an online environment are rather well described by the Self-Directed Learning Theory (SDL) and Self-Regulated Learning (SRL) Theory." SDL focuses on the student taking the <u>initiative</u> to pursue a learning experience <u>and</u> the <u>responsibility</u> for completing the work. SRL describes a process in which the student takes both <u>control</u> of the learning and of the process to <u>evaluate</u> their progress.

In line with other study results,[16] we did find that students do persist at a higher rate in the on-ground course (12.5% drop rate) as compared to online (30% drop rate) and gave the on-ground course higher ratings in the course evaluations. Most of the students that dropped the courses did so very early in the quarter and most were performing at least at an average level prior to dropping. While our study did try to increase the level of student connectedness to the courses these interventions did not match the value of connectedness (as reported anecdotally from students) achieved via interaction with the instructors and other students in a live course.

Other observations to the online, on-ground, and flipped course design include:

1. Email and other electronic communication are not natural channels for technical exchange. Piazza offers the opportunity to write equations and formulas, and insert figures and pictures, which is quite helpful for the instructor. Students, however, are less likely to use all of the features offered and, understandably, their ability to properly describe their questions and confusion in writing is somewhat limited.
2. The amount of effort needed to turn a fully flipped class to an online one is somewhat modest (see items 1-3 in the Study Design section above). The main effort is developing the online material that is also used in the flipped format.
3. Students can benefit from clear explanation of the goals and benefits of flipped format courses. For many, it is simply an increase in the workload (lecture time plus online segments). A proper explanation of the process and how it is designed to improve learning without extra time would be helpful.

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4. To avoid losing the interest and attention of students, the pace of the video segments must be relatively fast. At times, this can be frustrating to students as they conceive correctly, that their ability to master the material is compromised. Providing pdf versions of the notes (on which the narration is added) available would be helpful as many students wish to take notes while watching the segments. Having the source material will allow them to annotate the notes as they see fit and focus on the lecture.
5. While the numbers in summer of 2014 were not large enough to make strong statements, anecdotal evidence indicates a lukewarm level of interest among students for the online format (e.g., several students who had taken online classes before were offered the chance to enroll in the online class but they specifically chose against the online offering).

For perhaps most engineering students, studying is somewhat ritualized: organized around lectures (note taking) and homework (trying to understand the material enough to complete the assignment), and exams (studying). This is not necessarily the most appropriate path to learning. Flipped and online classes disrupt this process somewhat. Flipped classes require studying throughout the course (to engage in class) and reduce the importance of homework (as they are dissected and discussed in class or in on-line segments). The observations listed above are mostly related to the side effects of this disruption. While an argument can be made that the new alternative is superior (and closer to the ideal behavior), it requires acceptance and buy-in from the students to be successful. The most critical danger is that by removing the weekly guideposts (e.g., unassisted homework assignment) it will make it easier for students to focus on other courses and ignore the flipped course. This will lead to a class with two groups: those following the format and those detached. The latter group would be less prepared for the examinations, as the assignments are now less challenging and do not force the students to, at least, partially understand the material throughout the term. While for one class in isolation this might not be a significant problem, the proximity of multiple exams make the task of catching up quite challenging. Finally, timely feedback is a key component of this approach. Developing an incentive scheme (e.g., points for answering survey/poll style questions and engagement in discussions) that does not distract from the core learning goals of the course is a critical task that can be a function of other student characteristics such as student maturity (e.g., freshman vs senior level course).

The authors recognize the inherent biases in their dual role as both instructors and researchers, but argue that their tight connection to the student population and technical content allows them to evaluate and uncover insights in the data that would not be apparent to an outside researcher. The research team was, however, created to specifically include both internal and external viewpoints. Dr. Faryar Jabbari and Dr. Dave Dimas are both on the faculty in the School of Engineering and their roles are indeed both researchers and instructors. However, the third

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member of our team, Dr. John Billimek is a researcher in the Health Policy Research Institute in the School of Medicine and provides a valuable external, unbiased viewpoint.

It is important to mention that the 7 students who took the online version of the *Dynamics* course in this study would not have been able to take it during the summer. These 7 students were all accepted as junior transfers from community colleges planning to begin full-time study in the fall of 2014 as engineering majors. Had they not taken this class in the summer, they would not have been able to take key required courses that their freshman-start counterparts would be taking. This would have put them behind and put them at risk for not being able to complete their degrees in 2 additional years, increasing both their student debt and time-to-graduation. Plans are in place to ensure the summer 2015 online class is large enough to yield statistically reliable results.

Even with the limited sample size, these results support the possibility that online courses could be as effective as on-ground courses in terms of student performance. The trends in this data have given the authors motivation to continue to study these issues to help validate online, flipped, and hybrid courses as viable tools not only to help improve the matriculation rates of transfer students, but also to help improve the operation efficiency of teaching STEM courses at research universities and help the debt load of future generations of students.

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Service Learning in Engineering Management

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Abstract

It's not often that college students are able to put their coursework to use in a philanthropic way, but for Engineering Management students, that opportunity was made possible in the form of a 5K run. The purpose of the project was to allow students an opportunity to learn decision making and project planning while at the same time gaining exposure to the benefits of community service. Through this project, students engaged in scheduling, financial evaluation, benefit cost analysis, resource allocation, time/cost tradeoffs, team-building, progress monitoring and risk assessment. Future professional challenges involve real problems faced by real people living in real communities and contain both technical and non-technical elements. Integrated and collaborative educational experiences can help students to meet these challenges successfully. This project gave students an opportunity to overcome obstacles and step out of their comfort zones. Students learned the value of a committed team and gained confidence to lead and take risks, realizing that nothing worthwhile comes easily. Assignments, progress reports, a final report, and peer evaluations were used to assess student learning outcomes in a service-learning framework.

The purpose of this article is to present information that will help educators to incorporate this type of service learning project in their curriculum. This article first provides information about service learning and then presents a guide to implementing service learning in an undergraduate Engineering Management class.

Introduction

Engineering Management students had an opportunity to combine learning and philanthropy in the context of a course project in Fall 2014. This project went beyond a classroom exercise as it required students to coordinate and execute a 5K run to raise funds for a local non-profit organization. The project was designed to help students learn decision making and project planning while gaining exposure to the benefits of community service. Students learned the value of a committed team experience and gained confidence in leading and managing a project through its life cycle.

Successful completion of the course project required students to apply their knowledge of scheduling, financial evaluation, benefit cost analysis, resource allocation, time/cost tradeoffs, team-building, progress monitoring and risk assessment, as described in this paper. The project was integrated into the course and conducted over an 11-week period. Project elements were completed as topics were covered in the course. Students were divided into five self-selected project sub-teams covering the following areas: logistics, marketing, fund raising, registration and pre-post entertainment. Each sub-team was made up of a project leader, a project manager, and a secretary. Project deliverables included the 5K Run, but also included individual

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homework assignments, end-of-semester peer evaluations, weekly progress reports, and a final project completion report from each sub-team. The 5K Run Project will be repeated in Spring 2015, but with a new community partner. Lessons learned from the first iteration were identified and will be incorporated to improve the project and quality of student learning.

ABET Accreditation Criteria for Engineering programs require that accredited engineering programs demonstrate students have "an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability," and "an ability to function on multidisciplinary teams" [1]. The integrated and collaborative learning environment provided by the type of applied project used in this course can help prepare students to address problem solving to meet desired needs within realistic constraints while developing their awareness of community needs.

Active learning, cooperative learning, service learning, and problem-based learning have been shown to be effective classroom-based "pedagogies of engagement" [2] that enhance student learning through involvement and can help students identify the relevance of engineering education [3]. Alternative definitions of service learning typically characterize service learning projects as supporting the educational experience and addressing the needs of the community [3,4]. In addition to providing opportunities to develop their technical knowledge and skills [5], problem-based and service learning projects can help develop students' professional skills such as communication, team work, and project management skills, while also affecting their attitudes, confidence, creativity, and interest in engineering [6, 7, 8].

With an emphasis on project selection for capstone design, Brackin et. al [9] note that factors that can lead to project success include the level of students' interest in the project and the ability to stimulate students' creativity, both of which are present in service learning projects. Aspects of service learning projects that challenge students to think critically include the fact that the problem itself may not be well-defined in "engineering terms". Students must be able to communicate with non-technical clients, external stakeholders, or supporters, and students may face unusual obstacles not present in typical course projects.

Course Overview

Engineering Administration (EMGT 170) is a junior-level course that provides an introduction to engineering management practice and decision making using engineering economic analysis. As part of the course, students learn techniques for analyzing the economic viability of projects together with other aspects of rational decision making based upon time-dependent cash flow analysis. Aspects of business management within an engineering context, namely, the engineering procurement process, project management, and project scheduling are also covered in EMGT 170. The course project provides a framework within which many course topics can be applied and is used, in part, to meet the following course objectives:

- Develop problem solving skills relevant to economic-based decision making;
- Apply strategies used in project planning with tools such as a work breakdown structure (WBS), Statement of Work (SOW), and Responsibility Matrix;
- Participate in team-based exercises and problem solving; and

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- Develop written and oral communication skills as applied within an engineering and/or marketing context.

Project Description

For this project, students planned and organized a 5K run for a non-profit organization. The project helped raise students' awareness of community needs and helped raise funds for a deserving organization in the community. Students were responsible for all aspects of the project from start to end, including planning, management, marketing, fundraising, logistics, and implementation. General objectives for the project approach used were to:

- Enhance student learning, content integration and engagement by enriching the connection between classroom learning and real world applications, and
- Integrate the university into the community and allow students to be on the forefront of that connection.

Student learning outcomes addressed through this project and through related course topics were as follows:

1. Develop a strategic management process
2. Identify mutually exclusive projects; define revenue from, and cost of, each alternative
3. Develop a portfolio management system and rank alternatives based on selection models
4. Define organization structures and identify requirements of a successful project
5. Define a project communication plan
6. Create a Work Breakdown Structure
7. Estimate project times and costs
8. Select the best alternative using incremental Benefit Cost method
9. Calculate breakeven value
10. Develop a project plan
11. Identify the profile risk and develop a response
12. Measure and evaluate progress and performance
13. Write a final report (executive summary, review and analysis, recommendations, lessons learned) and evaluate the work of peers

<u>Evaluating Community Partners and Developing the Project Mission</u>

Any community organization approached for a service-learning partnership must be willing to work with students, its mission must be relevant to students[10], and its mission cannot conflict with the university mission. Students were asked to select from the following non-profit organizations:

- A local organization supporting foster youth;
- A local organization supporting homeless individuals and families;
- The local affiliate of The American Cancer Society; or
- Other local non-profit organization nominated by the students.

Students were divided into groups of three and given a homework assignment to evaluate the organizations by developing a SWOT analysis, a priority analysis, and a project screening matrix – topics that were covered in class. Each group identified their preferred organization using

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objectives the group developed for their analysis, then all analyses were discussed in class. Students were asked to reevaluate their choices given any new information, different objectives presented by their peers, and additional guidance provided by the instructor, then the class voted on their selected organization. The American Cancer Society local affiliate was selected as the community partner based on results of this iterative process.

As part of the evaluation assignment, the students were also required to develop a mission, vision, and problem statement for the project, considering the needs course objectives and the mission of the community partner. Using the knowledge and experience gained from the assignment, the class as a whole then developed the mission, vision, and problem statement for the project. The problem statement developed was: “To raise awareness and funds to support a cause while involving students in the community effort and incorporating service learning to enhance course outcomes.”

Project Organization and Management

Students were asked to list the project stakeholders and to identify their roles in the project. They were given time to discuss their list with other groups and submit the final list to the instructor. Project stakeholders and their corresponding roles in this project are shown in Figure 1. The next step was to develop the organizational structure. A senior management team was formed, comprising two students who could self-nominate or be nominated by others, then all students voted for members to serve. The senior management team was responsible for overseeing project tasks and project documentation, and for reporting the project progress to the instructor. With the help of the instructor they were able to identify issues and potential alternatives to resolve issues.

All other students in the class joined one of the following 3-person functional project groups.

1. Marketing: responsible for advertising the event
2. Fundraising: responsible for raising funds and other donations and procurement
3. Registration: responsible for registering participants
4. Pre/post entertainment: responsible for participant engagement
5. Logistics: responsible for logistical support

The arrangement of university and project entities related to this project is shown in Figure 2. Students in each group rotated roles weekly through the three roles shown in Table 1. Although the rotation allowed students to gain experience in each role, this process introduced some challenges that will be addressed later in this paper. The project organization was flexible in terms of resource utilization and therefore a matrix organization approach was used. The matrix approach is a hybrid organization form that combines elements of both the functional and project team forms in an effort to realize the advantages of both. For this project, the senior management identified any excess capacity on functional groups and temporarily reassigned members to other groups to balance workloads and to stay on schedule.

Due to the short (11-week) timeline, the project definition, planning and execution were performed iteratively throughout the project. Students defined the project scope and priorities, and developed a work breakdown structure (WBS) as an in-class assignment. Each team

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presented their WBS on the board using sticky notes. Following discussion among the groups, the class developed a comprehensive WBS to define each team's responsibilities and identify all deliverables. Throughout the semester the WBS was modified as needed to account for challenges or additional information that became available. Teams used project plans to monitor activities, track their progress, and identify adjustments needed such as changes to labor resources, budget, and dependency state of each task.

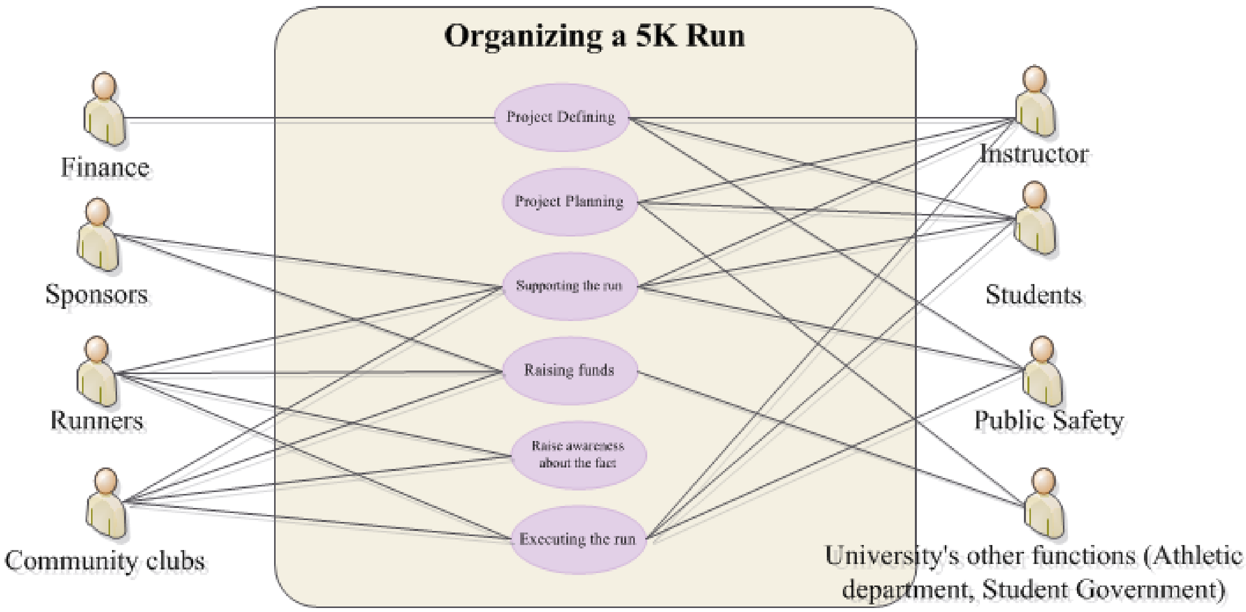

Figure 1: Use case diagram showing the stakeholders of the project

Two weeks before the event, students developed a Gantt chart as a group exercise in class and identified task relationships, estimated work packages (tasks that have a definite start and stop point, consume resources, and represent cost), and assigned resources. Ten days before the event the tasks, time to complete the tasks, resources needed to complete the tasks and each person's responsible for the tasks were reviewed and revised, as needed. The instructor and senior managers monitored the process closely.

Table 1: Team member roles and responsibilities

Role	***Responsibility***
Leader	Responsible for managing the group; making final decisions when needed.
Project manager	Responsible for managing and monitoring meetings; making sure that everybody contributes in meetings and that the project follows the plan and schedule.
Secretary	Responsible for writing meeting minutes and distributing to members; documenting activities in a binder that is submitted to the instructor weekly.

Project Strategy

To maintain project control and communication, each group met every week and submitted their meeting minutes and log book. The weekly reports were evaluated by the instructor based on performance and schedule measurements, total perspective of the current and future status of their work and recommended changes, if any. The group's project strategy included objectives,

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scope, assumptions, limitations, resources needed (people, equipment, facilities, etc.), and budget (money) for their project. Clear communication and frequent coordination between teams, senior managers and the instructor helped identify potential problems early on so they could be resolved. As part of the project strategy, students identified local companies, running clubs, and other organizations interested in offering help and guidance to students. These external organizations provided information and ideas to students during project execution and were available for questions during the project. For example, a local running club provided race planning information such as a timeline, equipment needed, and a comprehensive checklist that was a rich source of information for project planning and execution.

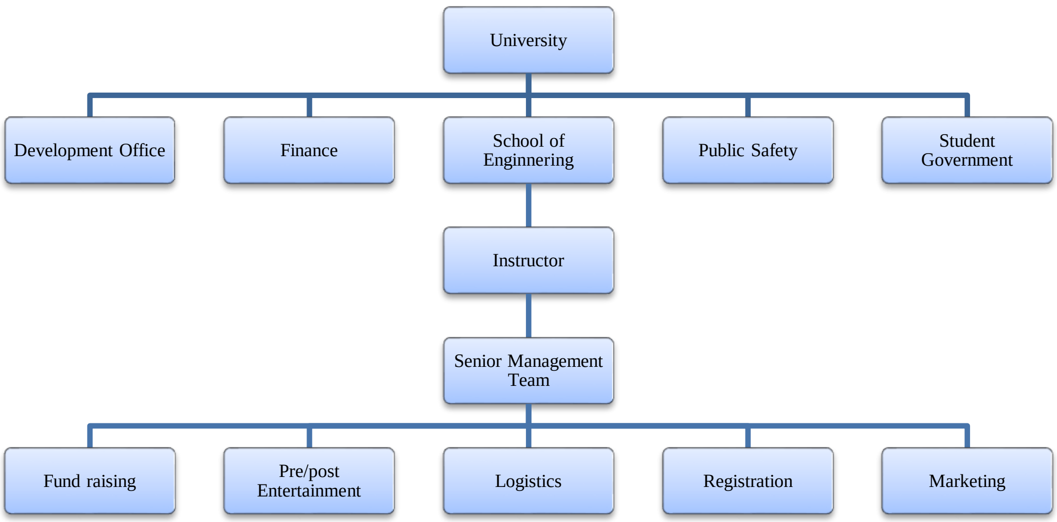

Figure 2: Organization hierarchy

<u>Risk Management</u>

Risk management is inherent to any engineering project, but is not necessarily familiar to students. At the start of the project, students listed the foreseen risks associated with the project as an in-class activity. Working in their groups, students identified possible impacts, and necessary contingency plans and funds to mitigate the risks. Students were also given a take-home assignment in which they completed a similar activity, as applied to the whole project: identifying potential risks, assessing implications of risks, responding to risks and developing contingency plans and finally, estimating costs and reserves needed for the whole project.

As students noted, the risk assessment paid off, as students had predicted some risks correctly (e.g. the DJ didn't show up and it rained) and were prepared to implement their contingency plans immediately on the day of the run (e.g. playing music from a smartphone, having multiple tents). The advance prediction and preparation were important learning opportunities.

<u>Economic Evaluation</u>

Economic analysis was included in the project, as specified in learning outcomes 2, 8, and 9, although different groups had a different basis for their decision-making. Students considered economic and non-economic factors in their decision-making process (e.g., to select t-shirt vs.

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headband, bottled water vs. water dispenser), then used a weighted attribute method to select an outcome and support the decision. Using estimates of donations received and number of registrants, students identified mutually exclusive alternatives and selected the best alternative using the incremental benefit cost method.

Project Report and Peer Evaluations

Upon completion of the project, each group submitted a project report on their group's component. Report elements included an executive summary, review of the group's work that included a reflection on strengths and areas for improvement, recommendations for this group if the project was to be repeated, and general and specific lessons learned. Report appendices varied slightly among the groups depending on their tasks. Groups appended elements that would be useful for future organizers to review such as meeting minutes, samples of documents and tools developed for the project, e.g., waiver forms and donation request letters, and information on suppliers and costs.

Previous studies [11] and student feedback in the authors' prior courses have demonstrated the usefulness of peer evaluations and effective team management to improve students' performance on teams and to address students' perceptions of fairness in grading regarding contributions to the team efforts. For this project, peer evaluations were conducted at the end of the semester. Each student was given the opportunity to provide input on the technical aspects of their sub-team members' contributions. The senior management team also evaluation each member based on level on of involvement in activities, and the quality of work in project defining, planning, executing and closing.

Race Day

The run itself was a successful event, despite having one of the very few rainy days in the middle of a drought year! Students arrived by 7 a.m. to set up, had music playing for motivation, and were well-coordinated by the senior management team. The route had been mapped previously by the logistics group and students were stationed at key points to direct participants. Approximately 70 runners and walkers and 35 volunteers attended, including friends, faculty, and family. Some runners completed the race in approximately 17 minutes, and the last walker arrived within 60 minutes. Spirits remained high - the students had organized for snacks and a gift bag for each participant and they held a raffle and awarded prizes for best costume and fastest runner in each category. The event raised $1,275 for the American Cancer Society.

Assessment

Students' performance on project elements was evaluated using both individual and group assignments. Individual work included homework assignments (e.g., breakeven analysis) and final exam questions and group work were included the project closure report, as shown in Tables 2 and 3. Service learning and problem-based learning provide flexibility to use a range of means to assess student knowledge, skills, and attitudes and the degree to which student learning outcomes are met. Examples provided in the literature include assignments, exams, community or client feedback, pre- and post-project surveys, reflection papers and journals, and peer

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reviews, among others [6, 10, 13, 14]. Chan [15] developed an assessment framework in which weighting was assigned to each component of the service-learning project, then a rubric was developed to assess some components. Cummings et al. [16] developed an instrument to evaluate student performance across the diverse learning experiences provided by problem-based service learning projects within the Engineering Projects in Community Service (EPICS) program at Purdue University. Both direct and indirect measures of student learning were used: student work (e.g., assignments) was used as a basis for evaluation in some areas while more subjective means were used in other areas. A similar evaluation tool was used by teams to self-evaluate their work and for the instructor to provide feedback.

Table 2: Assessment framework for service learning project

Assessment	***Assessed through***	***Assessed by***	***Weighting***	***Learning outcomes***
Weekly report (Time/Cost, status, meeting minutes)	Content and quality of the technical work	Senior mgt team, instructor	5% ×11 weeks	1-13
Performance on execution	Accomplishment of assigned tasks; communication; involvement; and capability to resolve challenges	Senior mgt team, instructor	10%	1-13
Performance (defining, planning and closing)	Knowledge about statement of work; communication and quality of technical work	Senior mgt team, instructor	10%	1-13
Project closure report	Content and quality of the executive summary, lessons learned and recommendations	Senior mgt team, instructor	20%	12
Involvement and communication	Active participation, Communication with team members and senior mgt team	Group leaders, Senior mgt team, instructor	5%	1-13

Table 3. Deliverables for project management

Week	***Assessment***	***Learning outcomes***	***Project vs Homework***
1	Statement of work; RACI; Communication Plan	5	Homework & In-class activity
2	WBS	6	In-class activity
3	Strategic Management Process [11]	1	Homework
4	Project Organization and responsibility	4	Project (5%)
5	Financial Analysis	7	Project (5%)
6	Project Planning and Decision Making	10	Homework
7	Procurement and Breakeven Analysis	9	Project (5%)
8	Estimating Cost	7	Homework
9	Alternative Evaluation Considering Multiple Attributes and Risk[12]	2,3,8,11	Homework
10	Progress and Performance Measurement and Evaluation	12	Project (5%)
11	Project Closure	13	Project (20%)

Lessons Learned

The Fall 2014 5K Run was the first iteration of this course project. Evaluation of the project, its deliverables, and student feedback revealed strengths and areas for improvement that can be implemented in Spring 2015. Significant strengths of the project included having an actual project management application with a deliverable, i.e., the run itself, and a community-based nonprofit partner selected by students. The sense of responsibility towards the project partner helped students hold themselves accountable for completion of the project. Equally important were recognition and gratitude expressed by the nonprofit agency's representative and university for the students' efforts.

As the project progressed, it was noted that students were able to complete short term, specific tasks, such developing as a RACI, performing a breakeven analysis or developing a WBS, but tasks that required long-term or big-picture thinking were more challenging. This issue will be addressed in Spring 2015 by providing more guidance on challenging tasks to break them down into manageable components.

Although the entire class of 15 students generally worked well as a team, senior managers noted that some students were waiting to be given tasks by the managers rather than taking initiative to complete their group's duties, or were unaware of progress within their group. Communication expectations and processes will be defined early on and used often to avoid issues. Additional guidance and weekly meetings with the instructor, senior managers, and a representative from each group may also help better address this issue.

Within each group, students rotated among the three roles. However, this was found to be rather confusing and created a break in continuity. Although students gained experience in each role, for next semester, the students will select and remain in one role, so that each team will have one point of contact throughout the project. If students decide to switch roles, the group will need keep the same point of contact who will share the information with the instructor, senior managers, and the rest of their sub-group.

Finally, an area for improvement identified based on evaluation of project closure reports in Fall 2014 was the need for more clear guidance on deliverables in terms of content and organization. Providing structure, or "scaffolding" through the use of rubrics, checklists, progress reports, and milestones can help students in achieving project goals by establishing clear expectations for performance and deliverables [17]. For the Spring 2015 course, additional instructions and a rubric will be provided and the quality of project closure reports will be compared to those submitted by the Fall 2014 class.

Summary

The course project incorporated into a junior-level Engineering Management course involved organizing and executing a 5K Run. Many course topics were applied through this service-learning project, including economic-based decision making methods and aspects of business management. In-class exercises, homework assignments, project binders, and a project closure report were used to meet and assess student learning outcomes. The commitment to work with, and help raise funds for, a local non-profit helped keep students accountable over the course of the semester. Overall, the service-learning project context was found to be a creative and useful way to help students learn the course topics, but assessment of outcomes revealed areas for improvement that will be incorporated in the next iteration of this project.

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Using Security Onion for Hands-On Cybersecurity Labs

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Abstract

Hands-on learning allows students to apply and better understand the concepts they learn during lectures and in reading assignments. Developing hands-on cybersecurity labs is challenging because many of the tools are proprietary and expensive. The creation of labs that simulate a real environment requires significant resources and planning. The use of real malware and network traffic provides a more realistic experience but can add additional risk to the laboratory network. This paper describes how we utilized the open source Linux distribution tool, Security Onion along with real malware and network traffic captures from publicly available sources to create a challenging and realistic set of hands-on cybersecurity labs. Security Onion is a Linux distribution that is used for intrusion detection, network security monitoring, and log management. It contains a variety of network security monitoring tools and is used by many organizations to monitor networks for intrusion. With its large number of pre-installed tools, Security Onion is an excellent tool to demonstrate network security monitoring concepts and provides students a hands-on experience with application tools commonly used by industry. In this paper we discuss the technical set up, development of lab objectives, data sources, and development of learning objectives. We also discuss mapping the learning objectives of the lab to the related knowledge, skills, and abilities in the National Cybersecurity Workforce Framework and to the relevant knowledge units required for designation as a National Center of Academic Excellence in Information Assurance/Cyber Defense. Use of realistic hands-on labs not only improves the students' learning experience but also better prepares them to enter the workforce.

Introduction

National University (NU) is a National Security Agency and Department of Homeland Security Center of Academic Excellence (CAE) in Information Assurance Education that offers a Master of Science degree in Cybersecurity and Information Assurance (MS-CSIA). Hands-on labs are a core component of the MS-CSIA curriculum. Providing students with labs that utilize the application tools and techniques used by industry can be expensive. The MS-CSIA program developed a set of labs utilizing the open source Network Security Monitoring tool Security Onion along with publicly available network traffic captures with malware to create a set of challenging and realistic labs.

Security Onion

Security Onion is an open source Network Security Monitoring (NSM) suite of applications used to provide full context and visibility into network traffic[1]. Network Security Monitoring is based on the collection, analysis, and escalation of indications and warnings (I&W) to detect and respond to intrusions [2].

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Security Onion is designed to facilitate deploying complex open source tools with an "easy-to-use Setup wizard" [3]. The Security Onion distribution includes a set of common network security monitoring and intrusion detection tools including Snort, Suricata, Snorby, and the BRO IDS, along with network analysis tools such as Wireshark and Network Miner [3]. It also includes the Enterprise Log Search and Archive (ELSA) tool which allows for consolidated log collection and analysis [3].The integrated set up allows students to seamlessly pivot from one tool to the next to learn the effective use of different network security tools. The ease of set up allows faculty to maximize learning by giving students more opportunity to use the tool, rather than spending time installing or troubleshooting; although students must configure different tools to perform the lab tasks.

Course Information

The Security Onion labs are conducted in course CYB 606 Net Defense and Countermeasures[4]. The course is designed as an introductory network security class that provides information on intrusion detection, network security monitoring, firewalls and encryption[4]. Prior to the hands-on labs, students complete lectures and assigned readings on the concept of network security monitoring, history of intrusion detection, and an overview of the different tools. The primary textbook for this portion of the class is "The Practice of Network Security Monitoring" [2].

Lab Environment

The National University Information Security Lab Environment (ISLE) is designed to provide a robust virtual environment for students as they perform hands-on cyber security training assignments. The ISLE is used for assignments throughout most of the NU MS-CSIA classes. The ISLE is implemented in a VMware vSphere 5.5 environment. There are four VMware hosts, each with four sockets, for a total of sixteen (8-core) processors and a memory capacity of 2TB. Total storage capacity is 20TB with capability to grow. The ISLE supports multiple user enclaves, which includes the CSIA Master's program and allows for isolation when working with real malware. Each of the user enclaves has an individual security policy. The implementation of multiple security policies is made possible by the use of next generation Palo Alto (PA) firewalls. The security zone functionality of the Palo Alto firewall is used to isolate individual enclaves from each other and provide each user community with both flexibility and assurance that their equipment will not be negatively impacted by other departments using the ISLE Infrastructure and vice versa. This isolation also prevents students from collecting unauthorized network traffic. For the CYB 606 labs, student are each provided with a Security Onion virtual machine with two network interface cards (NIC). One NIC card is for network connectivity and the other NIC card is for network traffic monitoring and data collection.

A master virtual machine with Security Onion installed and preconfigured with the required lab files is used for the class. Prior to the start of the class, the master virtual machine is updated and a copy is deployed for each student. Allowing students to utilize their own virtual machine gives them the opportunity to customize the tools and download other traffic captures and files for analysis. Each student virtual machine is allocated up to 60GB of storage and 4GB of RAM.

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Lab Design

The course labs were designed to provide an initial introduction to Security Onion and the tools installed in the distribution. The labs also demonstrate and reinforce the concepts of network security monitoring as discussed during lectures and with class reading assignments. Lab 1 has two parts. Part 1 is a walk-through that shows students how to utilize tools such as: Wireshark, Network Miner, squil, and Snorby. Part 2 requires students to conduct their own analysis of a second packet capture (pcap) file. The pcap files are used from a previous and publicly available Network Forensics contest [5]. Utilizing a pcap file, the students learn to extract a transmitted file and locate information in a TCP connection stream. Next, students replay a TCP file from an old honeynet scan of the monthly contest and learn how to review and analyze alerts in Snorby and squil [6]. Once students are familiar with these tools, they are given another task named "Ann Skips Bail" [7]. The purpose of this lab is to find some specific data in the pcap files. One challenge to using publicly available contests, is the easy availability of answers; especially for older contests. In addition to answering the specific question(s), students must provide a write-up of their methodology, tools as used with associated screenshots, and provide evidence supporting their conclusions. This not only provides a demonstration that students completed their own work, but helps them learn to write and document an analysis narrative and report their findings to senior management.

In the next lab, students act as an incident responder and must analyze a file with real malware. The file is from the Network Forensics Contest "Puzzle #5: Ms. Moneymany's Mysterious Malware" and contains a malicious Java Applet [8]. As with the previous lab, students must answer specific questions, such as originating URL of the file and MD5 hash of the malicious file. Students also provide an analysis in their own words.

A third lab requires students to practice creating encrypted volumes with an 'easy' password and a 'complex' password. Once completed, each student tries to crack their partner's encryption using different tools. A final lab challenges the students to practice hardening a Linux virtual machine by setting up a local firewall and running penetration testing scans against their partner's VM to observe the results. A pre-hardening scan is conducted to enable baseline results as a comparison against their probe.

Students are offered several options for a final class project. One project option is to utilize Security Onion to analyze a large packet capture. Some example of potential datasets are at the NETRESEC website [9]. As part of the project students must replay the traffic in Security Onion and use the various tools to analyze the traffic and identify such things as:

1. Network structure
2. Types of attacks
3. Phases of attacks
4. Potential preventative measures

Security Onion and NSM Display

The ability to provide over 60 custom tools, further extends the abilities, both automatically and manually, for the students to analyze the same data with different tools. . The powerful network analysis tools in the Security Onion distribution also provide a common framework for analyzing the data and provide a realistic environment for students.

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Learning Objectives

Mapping student labs to achieve clear objectives not only supports learning, but allows a student to provide demonstrable skills to potential employers. With the National Initiative for Cybersecurity Careers and Studies (NICCS), the Department of Homeland Security (DHS) and the National Institute for Standards and Technology (NIST) have created the Cybersecurity Workforce Framework [10]. The purpose of this framework is to identify the common knowledge, skills, and abilities of Cybersecurity workers, along with associated job tasks [10]. Table 1 provides a list of the tasks, knowledge, skills and abilities mapped to their associated framework category that students demonstrate by completing the assigned labs.

Table 1. List of Cybersecurity Framework Tasks and KSA's Accomplished in labs

Framework Category: Protect and Defend
Framework Specialty Area: Computer Network Defense Analysis
Tasks completed in the Labs
1. Analyze identified malicious activity to determine weaknesses exploited, exploitation methods, effects on system and information. 2. Characterize and analyze network traffic to identify anomalous activity and potential threats to network resources. 3. Identify and analyze anomalies in network traffic using metadata (e.g., CENTAUR) 4. Perform event correlation using information gathered from a variety of sources within the enterprise to gain situational awareness and determine the effectiveness of an observed attack. 5. Reconstruct a malicious attack or activity based off network traffic. 6. Use Computer Network Defense tools for continual monitoring and analysis of system activity to identify malicious activity. 7. Validate intrusion detection system (IDS) alerts against network traffic using packet analysis tools.
Knowledge, skills and abilities demonstrated in the labs
1. Ability to interpret and incorporate data from multiple tool sources. 2. Knowledge of different classes of attacks (e.g., passive, active, insider, close-in, distribution, etc.) 3. Knowledge of general attack stages (e.g., footprinting and scanning, enumeration, gaining access, escalation of privileges, maintaining access, network exploitation, covering tracks, etc.) 4. Knowledge of intrusion detection methodologies and techniques for detecting host and network-based intrusions via intrusion detection technologies 5. Knowledge of intrusion detection system tools and applications 6. Knowledge of network protocols such as TCP/IP, Dynamic Host Configuration, Domain Name System (DNS), and directory services 7. Skill in collecting data from a variety of Computer Network Defense resources 8. Skill in performing packet-level analysis (e.g., Wireshark, tcpdump, etc.) 9. Skill in reading and interpreting signatures (e.g. snort)

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10. Skill in using network analysis tools to identify vulnerabilities 11. Skill in utilizing virtual networks for testing
Framework Category: Investigate
Framework Specialty Area: Investigation
Tasks completed in the Labs
1. Analyze computer-generated threats. 2. Conduct analysis of log files, evidence, and other information in order to determine best methods for identifying the perpetrator(s) of a network intrusion. 3. Develop an investigative plan to investigate alleged crime, violation, or suspicious activity utilizing computers and the Internet.
Knowledge, skills and abilities demonstrated in the labs
1. Knowledge of system and application security threats and vulnerabilities (e.g., buffer overflow, mobile code, cross-site scripting, PL/SQL and injections, race conditions, covert channel, replay, return-oriented attacks, and malicious code)

Lessons Learned

The students' VMs are used progressively throughout the MS-CSIA courses, and in classes prior to CYB 606 they performed steps to harden their Windows and Linux systems. In starting the labs for CYB 606, some preliminary scans with Security Onion tools had very limited results, so students found they must reverse or disable some of the hardening measures in order to get more meaningful results from the vulnerability scans or penetration testing in the labs. This also taught them that, in some instances, system hardening is effective in protecting against certain types of intrusion attempts. From an instructional standpoint, because students come with such a wide variety of backgrounds and technical skills, the initial lab instructions must have clear, step-by-step procedures to help students learn about the tools and how to use them, followed by more open-ended instructions that let each student decide which tools to use to solve the lab assignment. Once students gain familiarity using the tools in week 1, they are provided less structure in week 2 and required to act as a security analyst. Students who tend to focus on a single tool should be advised to take advantage of the data linking between multiple tools to obtain the best results. Students are encouraged to compare the results obtained between the different tools to better understand each tool and to validate answers. Also because of the varied backgrounds, it is helpful to provide students with a response template for each lab, to ensure all necessary lab results data is reported in a consistent manner.

Security Onion is processor and memory intensive. During the first deployment of the labs 1GB of RAM was allocated for each virtual machine. This caused slow processing and poor video display. In subsequent labs, memory was increased to 4GB which enhanced performance and provided reasonable processing speed. Institutions without a virtual lab environment can still utilize Security Onion on local workstations or on student personal computers using a virtualization tool like VMWARE or Virtual Box.

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Distance Learning for Student-Inmates in Higher Education through Digital Mobile Devices

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Abstract

University students with particular constraints require alternative educational approaches that compensate for these limitations that they face. In fact, unable to follow traditional classroom training, "student-inmates" (Pike& Adams 2012) turn to distance learning. But today, unlike before, this practice is dependent on an Internet connection through learning platforms. Learning platforms allow the student's work to be organized, and for digital resources to be readily available, which can be submitted and reviewed. But also, students can communicate with teachers and tutors.

In France, except in experimental cases in a few penitentiaries, prisons are not connected to the Internet. Therefore, educational and technical solutions for this particular setting must be provided by instructors in higher education as well as instructional designers. The research presented in this paper is ongoing and it focuses on the project entitled, IDEFI (Initiatives d'Excellence pour l'enseignement et la formation innovantes)[i], at the University of Paul-Valéry Montpellier.

The objective of this project is to increase the success rate of student-inmates during their freshman year of university studies. For this population, this means receiving education through the use of digital mobile devices, promoting active participation. Following this approach, teachers involved create a pedagogical environment that fosters learning within the penal system. For example, cultural tours can be provided via video recordings for inmate research through digital platforms from students outside the correctional system. Educators in higher education also propose other activities that help maintain a link with the outside world.

In light of the existence of special educators in the prison context, digital mobile devices can provide support for the development and integration of best practices. Because of that, the assessment of the activities must be strictly individual and pedagogical resources should be installed on authorized mobile devices in correctional facilities.

Throughout this article, solutions are offered and examples are given on how distance learning can be adapted to the prison context through the use of digital mobile devices and more generally, adapted to an environment without Internet access.

The Contribution of Digital Pedagogy to Distance Learning Programs in France

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Distance learning education which formerly provided its correspondence through the mail, that is through postal services, has seen an expansion over the past several years due to the development of digital pedagogy through academic courses, but also through Massively Open Online Courses (MOOC). The use of learning platforms such as the LMS (Learning Management System) has created the possibility for teachers to offer print, sound and audiovisual resources online to students as well as self and collaborative learning activities within a pedagogical framework for educational purposes. This pedagogical approach is called "digital" because it is supported by information technology and by communication. In addition, it encourages teachers to transmit and acquire knowledge, skills and expertise at any place or time. It places students in an active position through their use of personal electronic devices and allows them to learn and to communicate with peers and teachers (Martin, MacGill and Sudweeks, 2013)3. However, the remote dissemination of teaching modules is not the only attractive component.

Digital pedagogy also allows lessons to be customized and adapted for different situations as shown through the applications of mobile learning (Nedungadi& Raman, 2012)4. Among those affected are those who live in geographical zones in which the wireless connection is weak or in the case of inmates in French penitentiaries where there is no Internet access.

Educational activities in prison are severely limited because of the absence of the Internet (Hancock 2010)2. In addition to the approach chosen by Pike and Adams (2012)5 which aims to "(...) identify what technology was available to student-inmates, how it was accessed and used to support learning and the cultural attitudes towards technology-supported learning in prison", we would like to emphasize the adaptive nature of distance learning.

Educational activities in prison are subject to penitentiary and educational mechanisms at work. These activities help those studying to form an "inmate-student" identity (Vettraino-Soulard 1980)8 and Salane(2010)6. They underlie the idea developed by Smith and Silverman (1994)7. This idea places the priority on giving the inmate an activity to participate in, a sense of something to do during his/her time in prison instead of giving him/her the goal of obtaining a diploma or finding a job.

Distance Learning for Student-Inmates

More specifically, we are interested in distance learning in higher education. This fits within the legislative and organizational framework where both institutions, universities and prisons, interact to preserve the right to an education for those in prison. The number of detainees in university courses is quite low : only 1.4% out of 46186 inmates in a course of study are working towards a degree in higher education. Teachers on site rarely have a university degree (the majority have completed one or two years of training to teach middle school or high school).

In France, these distant learning programs are offered by specialized services from universities or through the *Centre National d'Enseignement à Distance* (CNED)[ii]. Distance learning still remains the preferred method, "a first response adapted for this population"[iii].

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Some institutions put certain mechanisms into place in order to provide a university education close to the conditions in prison. One possible solution is the *Section des Etudiants Empêchés* (SEE) from the University of Paris – Diderot. Historically this was the first organization to offer university courses in prison as a result of the involvement with instructors in various prisons. It is similar to the University of La Rochelle, which also offers detainees the possibility to borrow books from the library through a distance lending system.

However, two main obstacles make this method difficult to implement. First of all, few or no universities offer programs to student-inmates. Next, the courses are either offered though paper resources because of the lack of Internet access or they are downloaded by the *Responsible Locale d'Enseignement* (RLE)[iv] of the prison, directly through the learning platform. In either case, the student-inmate has very little information about the final aims of the training.

Because of these obstacles, the idea presented by Decamps et al. (2009)1 of the course management, which describes how each player carries out a particular role in the learning environment, is well-suited to this context. That is why we are committed to working alongside the IDEFI project run by the University of Paul-Valéry Montpellier and more specifically through an initiative entitled "Publics Empêchés", whose objective is to encourage success in first-year university students, though customized methods of teaching and learning, within a learning environment with no Internet access.

A Situated Learning Approach without Internet Access

Because of the lack of Internet access as well as other constraints within the French penal system, French universities are pushed into taking an alternative approach to distance learning. To better understand this approach, we compare the two different learning environments: those with and those without Internet access.

Distance Learning Tool	Learning Context	
	With Internet Access	Without Internet Access
	Platform (LMS)	
Access to Training and to Instructors	Available for student to access different content material	Available for RLE No access for student
		⇣ A mobile support device is provided when educational resources are integrated
Contents	-Access to internal and external	- Documents in different formats

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	documents in different formats; -Integrated and external websites -Material and activity offerings on the platform -Access to online resources	- Integrated website - No access to online resources
		↓ Creation of documents and adaptation of documents already available
Activities	Individual activities and/or self-study; activities in groups and/or in collaboration with other individuals	Individual activities and/or self-study
Materials (Devices)	Personal mobile device or multimedia room on site	Multimedia room with restricted access
Communication between peers	Communication tools from the Internet platform and from social networks	Face to face discussion if the group has been formed within the establishment, if not, no communication
Communication with university instructor	Communication tools from the Internet platform	No direct relationship with the student nor experimental relationship via video conferencing
		↓ Creation of a record between the instructor and the student mediated through the RLE
Evaluation	Individual and in groups (collaborative)	Individual

The sections in color in the table above highlight the existing modifications with regard to the course management, from access to the course to its evaluation. Furthermore, we note that in the learning context with no Internet access there is neither support from exterior links nor is

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there communication between peers. It is precisely for this reason that the scenario-building and written content must be tailored to fit this alternative setting.

Methodology

The observations in this study are conducted through an ethnographic approach and the researchers take the role of participant observer. This study aims to understand what processes are involved in the scenario-building of the course and the resources that correspond to the specific features and constraints of the learning environment. To do this, we are studying a micro-situation: the modification of resources in first-year university students by teachers at the department of Humanities and Social Sciences. Within the framework of the IDEFI project, it is possible to distinguish the different integrated and/or interactive activities that contribute to a modification in the transmission of and/or the fundamental elements of a course. For this purpose, different data has been collected : records of the stages of the adaptation process of the university instruction between members within the project itself (meetings and individual interviews) and with the six teachers who taught first-year university courses. We are equally committed to taking dynamic screen shots to draw attention to the design in order to capture the best scripts built during the adaptation period in a specific learning situation.
Our role as participant observer involves our active participation in several modifications of the course as well as in the digital instructional materials for student-inmates particularly at the interface level and though Internet access. Details are given below of the modifications in the process of scenario-building.

Research Findings

In online education for student-inmates, university instructors have voiced different fears with regard to the design of courses than they normally would with traditional distance education courses. They are aware of the different demands of the situation that will impact their pedagogic choices according to the objectives of their course. But, it is interesting to see that the constraints imposed by the instructors in the activities and the instructional materials are not the ones that we introduced in the table describing the course management, which include:

- no Internet access and thus impossible to use the platform;
- direct relationship impossible except through the RLE
- lack of communication with other students and thus no peer support

In the first example, the instructor who was intrigued by this type of learning situation finds himself from the start facing a problem, as he is the one who designs courses for students and he " hadn't restricted their travel "[v]. This level of detail seemed complex to him because this course shouldn't be theoretical, but the teaching should call upon both real and virtual mobility, « This could have been, for example, a theoretical course like the one that I took as an introduction to word processing I think that I would have said that it was a form of EAD I'm getting used to it a little more, but like a course of media and cultural news it was to develop mainstream culture and for that reason, I asked to leave to change cultural practices a bit and go to a film to do a critique about the latest movies that I had seen at the beginning I felt held back and I said to myself how am I going to adapt to this course it's not possible»[vi].

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In the following case, an instructor describes a solution put forward by an instructional designer: " It was there that he was able to let go telling me that you had created a video where we could try to recreate the physical outings within a virtual space that I had asked my other students to do so it was really thanks to that work with the educational designers that I was able to let go and after that I had other ideas too and I told myself, well since they can't leave the penitentiary facilities I've got to think about the videos but at the beginning I was a bit blocked "[vii].

Thus it is the inability for student-inmates to move or travel outside the facility that produces a change in the instructional materials. It is the difficulty to reproduce distance education, as in a traditional setting, that pushes instructors, with the aid of instructional designers, to find alternative teaching/learning solutions to reach the course objectives.

In the second case, the instructor highlights the fact that the instructional output is not accessible by the university platform but through a portable support device (CD ROM or USB). In fact, the course materials produced are received first by the instructional designers that are responsible for setting up the support system, then by the RLE responsible for providing support and finally by the student-inmate. This multiple responsibility challenges the instructor, who is then worried about certain content that may not comply with copyright laws. It is for this reason that the instructor limits the number of images within in the instructional materials and asks for these items to be returned at the end of the year. This, at various levels, seems to the instructor, a constraint. The instructor thus adopts a more conservative attitude with regards to the content transmitted, claiming the need for strict compliance with copyright laws, a constraint that s/he may never have voiced before, within this learning context.

The third case makes reference to the need for the instructor to develop a meta-language and increase the amount of explanation provided due to the lack of information that the student has and the communication obstacles that exist between the instructor and the student. If the flow of information always seems possible through various forms of communication, " in general with EAD, I always put all of the info at the beginning on the platform on the evaluation I try to be the most detailed possible the most clear and there are sometimes certain things that I forget but the number of pages in the file (…) it's a time when they can ask questions (…) "[viii], it appears to no longer be the case for student-inmates. " So with student-inmates I have the impression that I explain quite a lot in my course lots of meta-language about the instruction because afterward I won't have the opportunity to communicate with the student and that was one of my worries that helped me with the IDEFI was to tell myself there that I wouldn't have to go back because I didn't know the student's last name first name if it was a girl or a boy (…) I wanted the course to be the most complete and most subjective possible so I put in a bit more text and a few more exercises to compensate for the lack of communication. "[ix]

As the documents supplied by this instructor show, the image is present in the original document for student-inmates. However, the image does not appear in the document that is intended for a wider audience of students in EAD.

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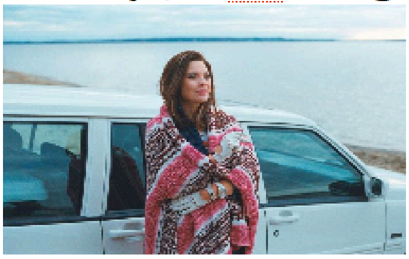
<table>
<tr>
<td>«Mommy», de cris et de grandeur

Anne Dorval, la mère de «Mommy». (Photo Shayne Laverdière)CRITIQUE

Rien à foutre, à fond et jusqu'au bout ! Le 5e film de Xavier Dolan bouscule.</td>
<td>«Mommy», de cris et de grandeur

Critique de Libération de le 06/10/14, par Gérard Lefort.

Mommy nous parvient à ce jour nimbé d'un boucan laudatif né en mai au festival de Cannes et qui depuis n'a fait qu'augmenter. Son jeune auteur, Xavier Dolan, gueule de mode idéale, mignon comme un cœur, a œuvré à intensifier ce déluge de dithyrambes, s'adonnant sans réserve aux couvertures de tous les magazines, à moult émissions de télévision.</td>
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<td>Extrait du document pour étudiant-détenu</td>
<td>Extrait du document pour étudiant EAD</td>
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</table>

The instructor, using this resource, compiled specific documents for student-inmates using meta-language and instructions but also with embellished content that compensate for the absence of communication. She also anticipated issues that could arise from this audience of learners through supplying additional support materials. Given the limitations in available information, she produced the most comprehensive resource possible.

Discussion and Conclusion

The findings from this research show that university instructors have broadened the scope of constraints, or brought forth new constraints, within the distance learning setting for student-inmates. It is interesting to note that the constraints found are those most closely linked to the design of instructional materials. In fact, this study does not only focus on the limitations found with materials, but it conveys a new analysis of an instructional tool that may be adapted for this specific learning context. University instructors connect the objectives of the lessons, the materials to be produced and the learning context directly with one another. They adapt indeed, creating resources in this specific learning context. They have also brought forth other variables in distance learning that were not necessarily taken into account before : (1) the inability to travel, (2) copyrights and intellectual property rights, (3) the development of a meta-language, of instructions and of content.

Situational and educational constraints play into the dynamics in the implementation of distance learning lessons. In order to adapt best to specific cases, a larger reflection must occur on the type of scenario-building that should be put into place. We can now ask ourselves how the modifications made in resources for student-inmates can benefit other students. Distance learning that occurs in a learning context without Internet access is a motor for the development of scenario-building of course content. Instructors are finding solutions for the limitations that at the beginning, as we remember, were the lack of Internet access and which hindered platform use, the impossibility of having a direct relationship with the student except through the RLE, and the lack of communication with other students, which meant no peer support. Teachers have embarked on broadening this debate of best practices in distance

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learning tools in comparing the two following learning contexts – those with Internet access and those without – showing how they are different and how each can enrich already existing practices.

Different players in the university setting hold a common belief that training courses should be adapted according to their educational framework. However there is still need for reflection from prison administrators about the political implications of possible Internet use in prison.

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[i]in Innovative Training and Education

[ii]National Center for Distance Learning

[iii] « une première réponse adaptée à ce type de public ».

[iv] Local Education Officer

[v] « n'avaient pas de contraintes pour leurdéplacement ».

[vi] « cela aurait été par exemple un cours théorique comme là sur ce que je fais comme l'initiation à la médiation des textes je pense que j'aurais dit c'est une forme d'EAD je m'adapte un petit peu plus mais là comme le cours actualités médiatiques et culturelles c'était pour développer la culture G je leur demandais justement de sortir de changer de pratiques culturelles d'aller au cinéma de faire la critique des derniers films qu'ils avaient vus là au début je me suis sentie un plus bloquée en me disant voilà comment je vais adapter ce cours c'est pas possible ».

[vii] « c'est là qu'il a réussi voilà à débloquer à me dire que vous aviez composé une vidéo qu'on pouvait aussi essayer de recréer sur un espace numérique les sorties physiques que je demandais aux étudiants donc c'est vraiment grâce à au travail avec les ingénieurs pédagogiques que j'ai pu débloquer après j'avais aussi d'autres idées je me disais bon comme ils peuvent pas forcément sortir du centre pénitencier essayer de réfléchir aux vidéos mais au début j'étais un peu bloquée ».

[viii] « en général avec les EAD, je mets toutes les infos au début sur la plateforme sur l'évaluation j'essaie d'être la plus détaillée possible la plus claire et il y a des fois des choses que j'oublie par contre le nombre de pages dans le dossier (...) là c'est un temps où ils peuvent poser leurs questions (...) ».

[ix] « alors qu'avec l'étudiant détenu j'avais l'impression que je fasse vraiment un cours très très expliqué beaucoup de métadiscours sur les consignes puisqu'après j'aurais pas la possibilité de communiquer avec lui et c'est ça qui a été une de mes appréhensions qui m'a aidé pour IDEFI c'était de me dire voilà que j'allais pas avoir de retour je ne savais pas son nom son prénom si c'était une fille ou un garçon (...) j'avais envie que les cours soient les plus complets les plus subjectifs possible donc j'ai mis un peu plus texte un peu plus d'exercice pour compenser aussi ce manque de communication ».

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Student Assessment: Focusing on Tests

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Abstract

In the university-level Computer Science courses it is a common practice to assess student learning by evaluating student performance in all components of coursework (homework, lab and project assignments, tests, etc.) and to assign letter grade based on the weighted average of all these scores according to some pre-defined distribution table[5,8]. This approach provides a comprehensive evaluation and allows every aspect of student performance to be factored in the overall grade for the course. However, such assessment does not always provide an accurate evaluation of student knowledge. In this paper we concentrate our attention on the introductory programming courses in Computer Science, even though the discussion can be extended to other CS courses, as well as to a number of courses in some other disciplines. We discuss certain issues related to the assessment of out-of-classroom assignments and pair assignments. We also point out some concerns that arise during the overall student evaluation, particularly connected to the weighted average grade calculation. As a conclusion, we suggest assigning the overall grade for the course based mainly on student performance in tests, while setting a minimum composite score for non-test components of coursework (homework, lab, and project assignments, etc.) as a requirement for passing the class.

Preface

The author of this paper has been teaching Computer Science for over three decades: first fifteen years in the USSR and remaining years in the United States. During her lengthy academic career she attended many major conferences in CS education, interacted and collaborated with many colleagues internationally, and published several papers related to the teaching of Computer Science. Observations and statements made in this paper are a result of discussions with about seventy five individuals teaching introductory Computer Science Courses in different countries.

Introduction

The evaluation of student learning is undeniably a very important aspect in the educational process. Student assessment methods vary from subject to subject, school to school, country to country[6]. In this paper the focus of discussion is the assessment of student learning in the

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university-level introductory courses in Computer Science. In these courses, student learning is typically achieved through lectures, lab assignments, and out-of-classroom assignments including homework and large programming assignments (usually called projects). In the United States, the student learning assessment in such courses incorporates the assessment of every component of coursework, and the overall grade for the course is typically based on the weighted average of scores for labs, projects, homework, and tests (e.g. midterm and final exams, lab tests, quizzes)[8]. This approach is comprehensive and thus is satisfying for instructors, since it allows a multi-aspect evaluation of student knowledge. It is satisfying for students as well, since it includes all portions of student workload and averages the results throughout the term – a low score in one course component can be neutralized by a higher score in another. This approach, however, does not always provide an accurate evaluation of student knowledge due to some unintended loopholes. Perfectly executed lab, homework, or project assignments do not necessarily indicate student's excellent knowledge or skills. In the following sections we will talk about problematic scenarios that appear during student evaluation and lead to an inflated overall grade for the course.

Homework Assignments

One of the common coursework components is the homework. The material discussed during a lecture is typically reinforced through a homework assignment: students are expected to review lecture notes, read respective textbook sections, and then do assigned exercises on learned topics. These exercises are meant to be done by students outside of classroom, and are typically turned in for grading. Homework grades are usually included in the weighted average grade calculation, and thus they contribute to the overall course grade.

As a component of student learning assessment, homework scores however may not accurately reflect student knowledge. When doing homework exercises, students may have questions and may need help; such help is provided by the instructor/TA/tutor and is limited to explanations and clarifications. However, it is not unusual for students to seek help from a third party. And this is exactly where the controversy lies. The problem is, that it is not possible to control or oversee the amount and nature of help provided by the third party – it may be as little as giving few clarifications, and as big as doing the whole assignment for the student[1,2,3]. If the purpose of homework assignments is only to help students master the material, this won't be a concern (by allowing someone else do the homework, the student deprives him/herself from a valuable learning experience, and will face consequences during tests). However, a problem arises when homework is included in the overall grade calculation and becomes part of the assessment.

Pair Lab Assignments

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An important component in introductory programming courses is the lab portion of the class. During lab sessions students typically get relatively small programming assignments that need to be worked on and completed in class and submitted/demoed for credit. Although labs can be done individually, a more common arrangement in introductory programming courses is to have students work in pairs. A significant amount of research has been done throughout many years suggesting that pair programming is a more productive setup for lab sessions of introductory programming courses[7,11,12]. Pair programming allows students to brainstorm and discuss strategies for the solution of the given problem, work in a team environment, and learn from each other. On the other hand, it allows the instructor to provide more help and give more attention to students, since there are fewer entities to oversee. Also, from the academic administration's point of view, pair programming is cost-efficient, since it makes it possible to increase the number of students in each class without major impact on student learning.

In introductory programming courses, lab scores are usually included in the overall grade calculation and thus become a component of student assessment. However, lab scores may not accurately reflect student knowledge. It is important to note that in pair programming the evaluation of individual student's performance is not straightforward and has some challenges[4,9]. The common practice in introductory courses is for both partners to receive the same score. However, when working on lab assignments, partners may not contribute equally. As a matter of fact, it is not unusual for one partner to ride on other's coattails. The truth is that even though students work in the classroom, it is not possible for the instructor to oversee and ensure equal workload distribution between partners in each pair. If the purpose of lab assignments is only to help students develop practical skills in programming and problem solving, this won't be a concern (by allowing the partner do most of the work, the student deprives him/herself from a valuable learning experience and will face consequences during tests). But a problem arises when lab scores are included in the overall grade calculation and become part of the assessment.

Project Assignments

Another important component in introductory Computer Science coursework is project assignments. These are larger out-of-class programming assignments that need to be executed and turned in for grading. Since projects are "at home" assignments, all above-mentioned issues/problems in regards to homework can be applied to them as well[10]. Additionally, since projects may be set up as pair assignments, all above-mentioned issues/problems in regards to pair lab work can be applied to them as well.

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A perfectly executed project assignment is not necessarily a reflection of student's flawless performance, even when no academic dishonesty was involved. The truth is that a notable amount of students, particularly struggling students, heavily rely on the help provided by the instructor (or the TA/tutor) during office hours. Unlike homework, where the help usually consists of additional clarifications and explanations, in project assignments the most sought help is in code debugging. Of course, even the best students on occasion can have a flaw in their code that they cannot find on their own, so a quick stop during office hours can help them fix the problem and have the program run perfectly. But the problem arises when a student writes a completely confused code and seeks instructor's help repeatedly, day after day, by visiting every office hour (and staying as long as possible) until all flaws are ironed out. The program eventually runs perfectly and earns a perfect score, but is it a fair and accurate assessment when in reality the student couldn't write reasonable code and couldn't find and correct his/her own mistakes? Unfortunately, this scenario happens more often than one may think; in fact, it is not uncommon that in introductory programming courses many struggling students end up with high scores in project assignments. For example, analysis of project scores (5 projects total) in Data Structures class (90 students total) in Fall 2013 quarter shows that the class average is 84.5%, and the average scores for the bottom 1/3 and 1/5 of the class are not much lower: 81.23% and 80.57% respectively. However, test results show a different picture: while the class average is 75.89%, the average scores for the bottom 1/3 and 1/5 of the class are 60.46% and 55.76% respectively. Note that "bottom" is in respect to students' overall-grade for the whole course.

Overall Grade Calculation

The final grade in introductory Computer Science courses in the United States is typically assigned based on the overall grade for the course, which is the weighted average of the scores for labs, projects, homework, and tests (i.e. midterm and final exams, lab tests, quizzes, etc.). The distribution of weights in the overall grade calculation varies from instructor to instructor, from course to course, from school to school. In many schools the requirement for passing introductory Computer Science courses is to receive a C- or better grade, which usually is associated with a 70% or higher overall grade for the course.

More commonly, in introductory CS courses the lab, project, and homework assignments together contribute 30-40% toward the calculation of the overall grade, and the rest comes from different tests. Due to such distribution, a student who has near-perfect scores in labs, projects, and homework assignments but performs very poorly in tests (earning around 50% in average), is able to pass the course; with 40% of the grade coming from the labs/projects/homework, this student's overall grade totals to 70% which leads to a C- for the course. However, as discussed in above sections, a high score in labs, projects, and homework may not be the actual reflection

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of student's knowledge and skills. This means that a student with very poor performance in tests, and questionable performance in remaining coursework, is able to move on to the next course. Accurate assessment in introductory courses is essential in ensuring that students are adequately prepared for the following, more advanced courses of the curriculum[5,8]. Insufficient knowledge and/or skills in introductory courses represent a major hurdle for a student; the lack of necessary foundation causes problems in the following courses, and more often than not the student fails eventually. For example, grade check of 10 lowest test-score earning students who passed Data Structures course in Fall 2013 shows, that in the following (Systems Programming) course 5 of these students received an F, 1 student withdrew and submitted a request for change of major, 2 students received a D, and 2 students completed the course with C- and B- grades respectively.

It may seem that lowering the weight of lab, project, and homework assignments in the overall grade calculation can solve the problem. We have experimented with that in Data Structures class three quarters in a row (180 students total, 60 students per quarter); we decreased the total weight of lab, project, and homework assignments to 25% (allowing 75% of the weight to go to different tests), and applied a flat-scale curve in the course grade distribution to compensate for the change. However, it created dissatisfaction among students; surveys conducted after each quarter of this experiment came to show that a significant number of students (averaging to 75% per quarter) felt that the amount of work involved in lab/project/homework assignments deserved more weight in the overall grade calculation.

Student Assessment Based on Tests Only

Labs, projects, and homework are important learning tools in introductory courses of Computer Science. Having them graded, to provide feedback to students, makes them also a teaching tool. And incorporating their scores in the overall grade calculation turns them into an assessment tool. Students' motivation often is directed toward the course grade, so they tend to view labs, projects, and homework mostly as an assessment method, and therefore they focus their energy on getting high scores for these assignments. As discussed above, it is impossible for the instructor to oversee and control the work process on out-of-class and pair assignments, and thus academic dishonesty may go unnoticed[10]. Even without any academic dishonesty present, the amount of help a student receives from the instructor/tutor/TA or a lab-partner, may make it difficult to indisputably credit the work as a result of student's own knowledge or skills.

Of course it is a well-known fact that cheating occurs during tests as well, and as research shows, in recent years unfortunately it has increased with the advances of technology[1]. However, tests are supervised/proctored activities, and cheating on tests is a serious but a different issue. In this

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paper we focus on coursework that is executed outside of instructor's direct supervision where boundaries of allowed collaboration and/or provided help may not be controlled.

To provide a more accurate assessment of student knowledge, we propose focusing solely on tests, including quizzes, lab tests, midterm and final exams. Lab, project, and homework assignments are invaluable learning and teaching tools, and we suggest using them in that capacity only. They still need to be checked and graded to provide feedback to students, but we suggest not including their scores in the overall grade calculation for the course.

Additionally, we propose establishing a minimum boundary for the composite score for homework/lab/project assignments as a requirement for passing the course; this means that students can't pass the course without earning at least the minimum score for these assignments. Doing so will retain student motivation and will ensure that these components are not ignored.

When shifting from an assessment system that includes lab, project, and homework components to the proposed one based solely on tests, we recommend adjusting the course grade distribution (perhaps considering a flat-scale curve with lower minimum boundaries for each letter grade).

We believe that basing students' overall grade on test results will bring more accuracy to student assessment. It will also eliminate the temptation for students to cheat or ride their partner's coattails in labs, projects, and homework. These assignments will simply serve as training tools to help students learn the material and develop/practice their skills. We believe students' focus in doing these assignments will shift to learning as opposed to getting a higher grade.

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Linking a Senior Civil Engineering Water Analysis Laboratory to Public Education

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Abstract

Water quality engineering requires young engineers to be able to clearly communicate complex topics to the public at a level appropriate to people's education regarding water issues. To help students acquire this skill the senior level water analysis laboratory curriculum of the Water Treatment Engineering course was designed to include a pilot research study. The students learned how much Cal Poly Pomona residents know about water issues and linked the results to the impact of the engineering practices. In addition to the traditional technical laboratory requirements, students enrolled in two lab sections were tasked with developing, implementing, and analyzing a survey of Cal Poly Pomona residents regarding their knowledge of water issues. Educational gaps were identified and instruments were developed for public education. By the end of the quarter, engineering students became aware of the impact of the professional engineers in society, and acknowledged that contact with the community would support the development of the best engineering solutions. The video products of student work were shared with lower level engineering classes and with other non-engineering communities at on-campus events that promoted environmental sustainability and awareness of California water challenges.

Introduction

Water has been cited as the most valuable resource of California [6]. Agriculture is a major industry that consumes from 52% to 70% of the total water demand in the Southwestern region of California[1]. Southern California's agriculture depends on water availability to produce food products for the country. While approximately two-thirds of the residents of California live in the Southern California area, only one-third of the water consumed comes from local sources. The remaining water demand is met by water imported from the Colorado River, the Owens Valley, and the State Water Project via a complex, state-of-the-art network of aqueducts comprised of miles of pipelines, channels and tunnels, pumping stations, treatment plants, dams, reservoirs, and hydroelectric plants [1]. Over the past several years there has been a significant reduction in the amount of water imported from the Colorado River, the State Water Project, and the Los Angeles Aqueduct (Owens River Valley). Along the Colorado River, the two water storages (Lake Mead and Lake Powell) remain below half capacity [2]. In addition, the water supply from the State Water Project and the Los Angeles Aqueduct has been reduced for the protection of endangered species and habitat restoration [4,5].

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Since the 1990s, water managers modeled water allocations and transfers to address concerns about water availability vs water demands of the regions served [3]. Water allocation reductions have required local agencies to find ways to reduce Southern California's dependence on imported water. Most efforts have been directed to the management of groundwater basins for water production and water storage, and to the use of advanced water treatment and wastewater treatment technologies for the reclamation of water that would not otherwise be available for public use or recreation [1]. Water availability issues have prompted lawsuits and policy development to ensure that water quality is sustained and that water is equitably distributed among all users.

Literature is rich in studies that attempt to analyze public perception regarding water issues and water education [7,8,9,10,11]. Water experts have realized that community perceptions, attitudes, values and behaviors concerning water vary from region to region [12]. People's attitudes and behavior regarding water issues are complex responses that incorporate regional characteristics, family background, public education, and the influence of the media. Southern California water companies (MWD, Orange County Water District, Golden State Water Company, etc.) are interested in identifying water issues that their consumers face. To collect information, the companies have sent surveys attached through their monthly water bills. Public agencies have used the data to develop internet resources and water education programs for K-12 instruction so that consumers can learn about Southern California water issues. In addition, information programs have been developed to educate communities about new water programs or innovative engineering solutions (like the water-to-tap).

The objective of the course change was to pilot the enhancement of the curriculum with an assignment that would mimic local community outreach efforts in Southern California water agencies, and as a result, providing contact between engineering students and the surrounding community as a way to support engineering students in developing skills to incorporate public's opinion in proposed engineering solutions.

Course Background

The curriculum of the senior level CE 431 Water Treatment Engineering course includes a lecture and a laboratory. The lecture portion provides information regarding drinking water policies, and is focused on conventional water treatment processes to achieve the design of a drinking water treatment plant. The laboratory portion of the course focuses on introducing students to the history of California water sources, and on the water analysis training, and testing practices to comply with drinking water standards. Specifically, the CE 431 Water Treatment Engineering laboratory technical curriculum includes:

- History of water in the West and California.
- Wet chemistry laboratories to evaluate turbidity, jar test, dissolved oxygen, pH, coliform bacteria, true and apparent color, temperature, alkalinity, chlorine, iron, total dissolved solids, microscopic evaluation, and acidity (Figure 1-top left).
- Analysis of results, evaluation of drinking water standards, and report preparation.

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- Field trips to water treatment plants (Figure 1- top right), and surface water reservoirs (Figure 1- bottom left).

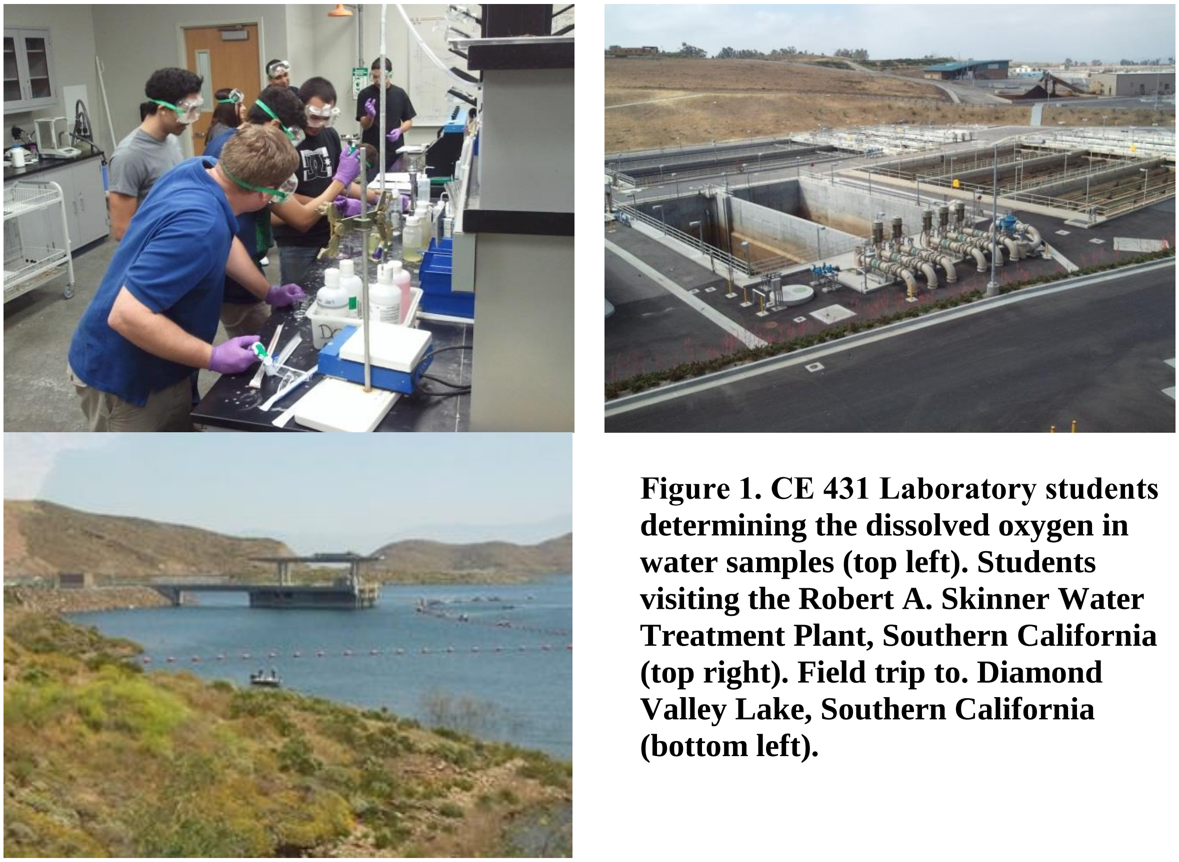

Figure 1. CE 431 Laboratory students determining the dissolved oxygen in water samples (top left). Students visiting the Robert A. Skinner Water Treatment Plant, Southern California (top right). Field trip to. Diamond Valley Lake, Southern California (bottom left).

The curriculum has been historically concentrated on the technical training to support students' engineering judgment skills, which will be applied professionally later when planning, designing and/or managing a drinking water system. In practice, successful engineering solutions should consider community beliefs, and knowledge of water related issues. Such skills have not been included as part of the course curriculum outcomes.

The pilot public education research project was conceived to provide students with the experience of communicating with the surrounding community. Contact with the community supports the achievement of the following ABET a through k student outcomes [13]: understanding of ethical responsibility (f), the ability to communicate effectively (g), the impact of engineering acts in societal context (h), the recognition of problems and real needs (i), and the knowledge of contemporary issues (j). Two laboratory sections, taught by the same instructor, were selected to conduct the pilot study. At the end of the term, pros and cons were analyzed to evaluate the permanent incorporation of the research project as part of the curriculum.

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The pilot study allowed the enhancement of the CE 431 Water Treatment Engineering laboratory technical curriculum with the following:

- Addition of a community interaction and public education research project.
- Addition of a final research project presentation: *How much do Cal Poly Pomona residents know about water?* to report and share the results of the experience

Methodology

Successful implementation of novel engineering ideas or water conservation practices requires that the practicing engineers have skills to identify community's knowledge gaps, can support the development of public education tools, and can clearly communicate complex engineering concepts to non-engineers. The overall objective of the research project "How Much Do Cal Poly Pomona Students Know about Water?" was to enrich the engineering rigorous technical experience with community interaction through the development of a research survey and the gathering of data within the Cal Poly Pomona community.

Working in teams, CE 431 laboratory students conducted the following activities:

1. Based on the initial five weeks of technical training, team members identified and ranked the top eight concepts that any California resident should know about water.
2. Using their five most important and critical facts that any California resident should know about water, teams designed five-question surveys. Surveys included questions that fit a basic Likert scheme of "Strongly Disagree / Disagree / Neutral / Agree / Strongly Agree." Surveys were anonymous, but included a question identifying the college to which the responding subject was associated and his/her occupation.
3. Each team was required to provide a minimum of 20 surveys.
4. Data was plotted per question, with Likert scale categories on the "x" axis and the frequency of responses in the "y" axis.
5. Each team identified a major water-related technical knowledge gap as identified in the survey responses.
6. Student teams selected a public education theme and developed an educational instrument (video, pamphlet, physical model).
7. Team reports and educational instruments were presented (orally) to the class.

Results

During the first five weeks of the laboratory course, students learned about the history of the drinking water sources in California, the quality of water in its natural state (surface and groundwater sources), parameters used to monitor water quality, history of water policy, and drinking water standards to produce potable water. Students tested different on-campus water

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samples, and evaluated their quality using the EPA National Drinking Water Quality Standards. Students evaluated the quality of their home drinking water sources by looking at the water quality reports of the conveying water utility. The first five weeks of the course had the objective of immersing students in technical water facts and trigger their curiosity in regards to their own water-use habits, and their own practices when choosing their primary sources of drinking water.

Development of surveys: Through the discovery that took place in the first weeks of the course, students developed an informed attitude regarding water issues in Southern California. This new, informed attitude helped students to identify the most important eight facts that any member of the community should know to be able to make informed decisions related to water availability and conservation practices in California. Once the students identified eight core facts, the facts were ranked. Student teams used the top five facts to develop their surveys.

Samples of Survey Hypotheses: Before developing survey questions, student teams developed hypotheses regarding the Cal Poly Pomona community's knowledge concerning water-related topics. Some samples of hypotheses formulated by the students are:

- Few people outside of the College of Engineering have knowledge about surface water treatment.
- The Cal Poly Pomona community is confident that tap water is safe for drinking.
- The Cal Poly Pomona community is aware of the drinking water regulations.
- The Cal Poly Pomona community is aware of quality issues associated with drinking water.
- The Cal Poly Pomona community conserves water regardless of their financial situation.

Samples of survey questions developed by student teams are shown below:

- Bottled water is just as safe as tap water.
- Water should not be wasted just because one can pay for it.
- Knowing where one's drinking water comes from is important.
- Safe drinking water cannot be determined by color and taste.
- Clean drinking water is a scarce and valuable resource.
- I trust the government's enforced drinking water standards.
- Drinking water should be pure water and have no other chemical in it.

Results of student surveys. Students reported that the most frequently identified knowledge gaps in the Cal Poly Pomona community were associated with the following topics:

- Opinions between tap water and bottled water as drinking water source.
- Steps in the drinking water treatment process.
- California water scarcity issues.
- California water history.
- Water quality parameters.

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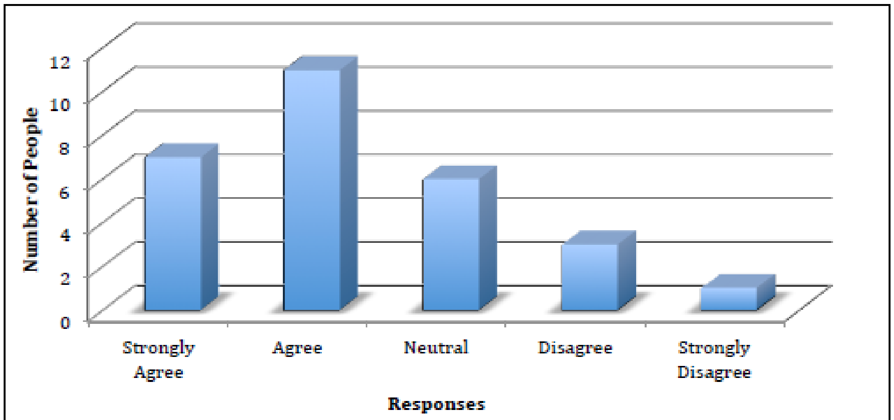
Illustration of the critical thinking process that students experienced is demonstrated by some samples of the data analyzed (shown below). Students hypothesized that Cal Poly Pomona community was confident that tap water was safe for drinking. However, student survey data consistently indicated that the majority of the respondents felt that bottled water was a safer drinking water source compared to tap water (Figure 2). While the format used to show the results varied, the majority of students were effective on graphing survey results.



Graph 2. Question 2: Bottled water is safer to drink than tap water.

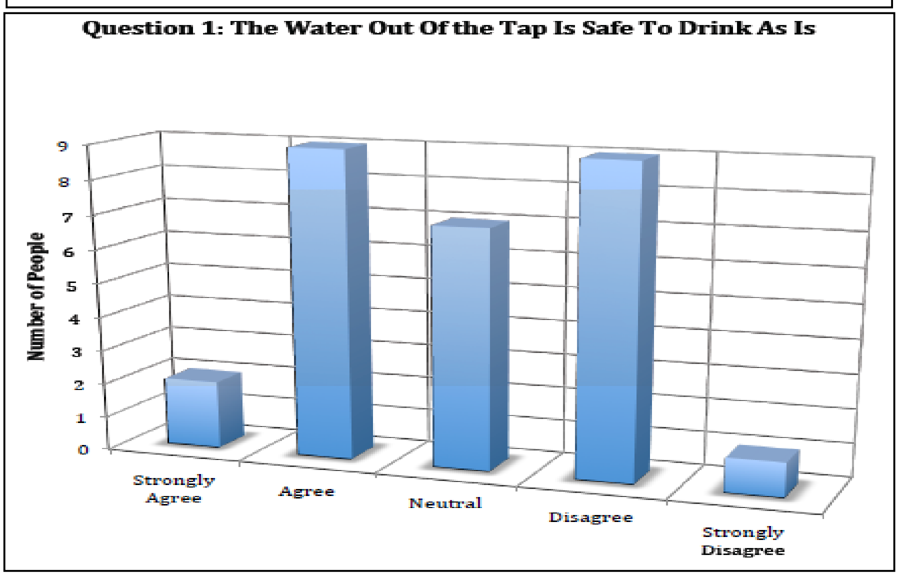


Figure 2. Bottle water vs tap water as source of drinking water.
***Graphs extracted from student reports.**

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In the analysis, students considered neutral responses as indicative that the Cal Poly Pomona community does not have enough information to make informed decisions regarding quality of tap water vs quality of bottled water.
Some students were interested in discovering if water was seen as a commodity that should be available primarily to those that can pay when using the item ("If a person is willing to pay for it, it is fair for them to use as much water as they want and in any way they like."). Students interpreted the results indicating that the number of responses in the agree and disagree scales were similar, while the amount of respondents that remained neutral (similar to the number of responses that agreed) was large enough to say that CPP community had never thought about the cost of water and its relation to water use (Figure 3). These results created concern among the engineering students regarding the community's attitude toward water rights. Students expressed that the quantity of water used by one person should not depend on their capability of paying or not for it, but it should be based on making the correct choice when using water. In addition, engineering students reported that the size of the sample needed to be larger to ensure accuracy of responses. Students became curious about the accuracy of the results of their survey responses, and whether they were representative of the whole CPP campus.

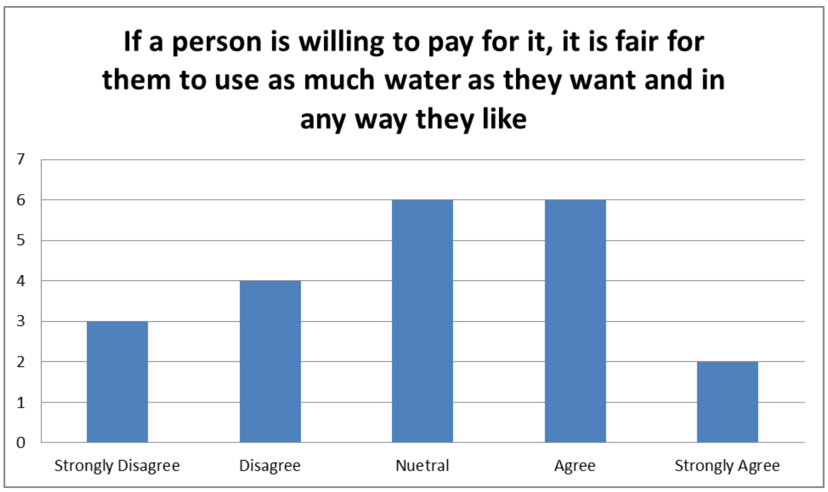

Figure 3. Water as commodity. *Graphs extracted from student reports.

Some students were interested in evaluating the knowledge that the Cal Poly Pomona had regarding the quality and the aspect of their drinking water, using the statement "You can tell if water is safe to drink by its taste and odor." Student reported that in general, respondents associated the lack of odor and lack of taste of water with a safe drinking water source (Figure 4). While Figure 4 shows that the results obtained indicate that the data was bimodal and that there was evidence of split knowledge of respondents, students reported that neutral responses were considered as indicative of lack of knowledge to judge the safety of the water by its taste and odor. Responses to this question led the engineering students to consider that respondents

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had little knowledge regarding water quality and the potential contaminants that could be present in tasteless and odorless waters.

<u>Student reflections.</u> The engineering students reflected upon their experiences surveying the Cal Poly community, and after analyzing the collected data. Sample statements as written in the engineering reports are shown below.

"Questions were mostly answered among agree, neutral, or disagree, showing that Cal Poly students were not fully confident in their answers."

"The combination of our interviews and survey data showed that many people had not even given much thought to their water. This was not surprising though; we had assumed that we would run into very few people outside of the college of engineering who would just happen to have surface water treatment knowledge."

"The results of our surveys can be summarized into three conclusions:

1. *There is a significant misunderstanding about what constitutes safe drinking water at Cal Poly Pomona.*
2. *Most people acknowledge that water is a scarce resource and the importance of its source.*
3. *People's opinions on the extent of water conservation differ greatly and needs to be addressed by the media, educational institutions, and the government."*

"Our major conclusion based on the survey results is that a primary issue with water education is the idea that our actions should reflect how important, scarce, and valuable water is. It appears that most people are aware of water's importance, but how we should use water and the idea of water conservation varied greatly among individual respondents."

"*Our question that "If a person is willing to pay for it, it is fair for them to use as much water as they want and in any way they like" revealed what we believe to be the key issue with water education on our campus. There needs to be more education about the importance of water conservation and how it is the responsibility of individuals to make the correct choice on water usage because the water issues of California affect us all*."

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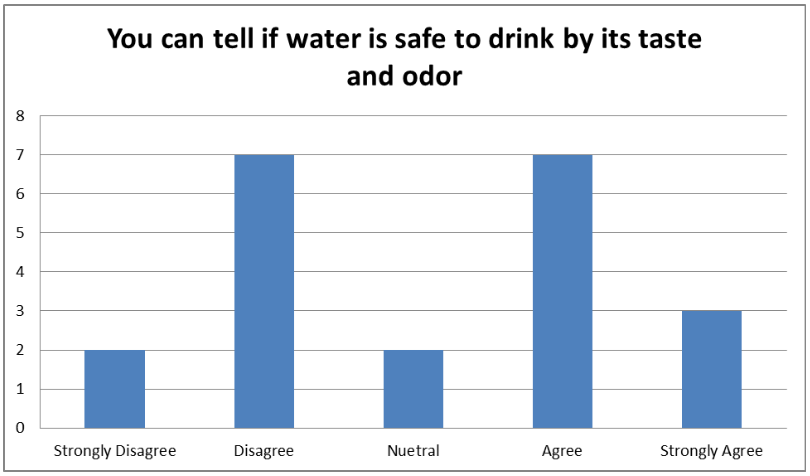

Figure 4. Use of senses to determine water quality.
***Graphs extracted from student reports.**

Student Reports. Overall the student reports demonstrated that students were able to 1) use their technical knowledge to identify the most critical concepts to be shared with the community; 2) use simple words to accurately communicate engineering concepts; 3) read current news and technical reports, and discuss the acquired information with community, peers and instructor; 4) demonstrate awareness of the ethical issues around water use, water cost and water availability; 5) recognize the impact of the water treatment engineering activities in society, and its relation with the education level of the community; 6) recognize that community education had not impact on the safety of a drinking water system; and 7) recognize that community education would improve public water conservation practices which will positively affect water systems management and conservation efforts.

Student educational instruments. To communicate selected water facts, students had to develop an educational instrument to educate the community. All the teams decided to make videos (Figure 5). The topics most frequently covered in the videos included: water quality, steps of water treatment, history of California water projects, drinking water standards, importance of water in the community development, and civic responsibility toward water use, among others. Videos were designed to fill the knowledge gaps as identified by students in their experimental results. In addition to be instruments for community education, videos were evidence of the technical knowledge acquired, and were evidence of the proper use of technical terms used to communicate with others. The language used in the videos was, in general, simple enough to be understood by the community and with an appropriate technical level.

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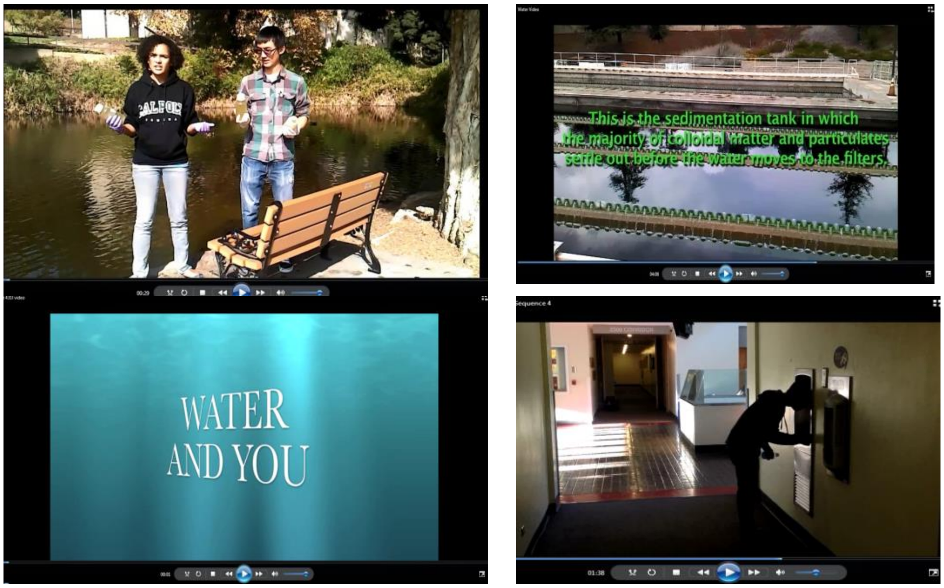

Figure 5. Water education videos

Conclusions. The activity allowed engineering students to conduct analysis of social data, and to link water education with the responsibilities of professional engineers. Community contact provided a first-hand experience with the ethical responsibility of a professional engineer, and with the impact of engineers in the surrounding community. In addition, the activity allowed the participating students to identify a current local issue and to propose solutions to educate the CPP community.

Completion of the survey project allowed the achievement of the ABET student outcomes as shown below:

- Students became aware of California's water quality and quantity issues via recently published reports and current standards. In addition, the experience via contact with Cal Poly Pomona community allowed students the opportunity to recognize knowledge gaps (problem), and the need for education (Supported achievement of ABET student outcomes i and j).
- Students created survey questions and personally sought community participation to collect the data. Students prepared reports and presented the results of their work to peers and instructors. One of the outcomes of the project was the educational instruments, which in form of videos targeted the education of the CPP community (Supported achievement of ABET student outcomes g and h).
- Students demonstrated awareness of the ethical issues surrounding the water use practices (use and cost, education vs water safety), and of the role of engineers in public's education (Supported achievement of ABET student outcomes f, h and i).
- Students acknowledged that survey sample size needed to be increased to reflect an accurate state of Cal Poly Pomona water education. In general, engineering student findings reported that there is a lack of understanding of what constitutes safe drinking

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water and how important it is to conserve water (Supported achievement of ABET student outcomes j).

Via the research project, students were able to link current water issues with knowledge gaps in the Cal Poly Pomona community. Students acknowledged the importance of educating the community to change attitudes related to water use and conservation practices in Southern Californians. Through contact with the Cal Poly Pomona community, engineering students realized that their work as engineers would support society's well-being. Students showed genuine interest in learning about technical aspects of water quality, and their role and responsibility as future professional engineers in community education. The discussions and conclusions in the engineering students reports, and the arguments provided during the oral presentations provided qualitative evidence that the ABET f through j student outcomes were achieved at different levels, via the pilot research project.

By the end of the quarter, engineering students became aware of the impact of the professional engineers in society, and acknowledged that contact with the community would support the development of the best engineering solutions. The video products of student work were shared with lower level engineering classes, and with other non-engineering communities at on-campus events that promoted environmental sustainability and awareness of California water challenges.

Impacts beyond the piloted classroom:

1) The videos produced by the engineering students have been used to teach younger engineering students and other Cal Poly Pomona non-engineering students about different water-related topics identified as a right-to-know.
2) Motivated by this pilot laboratory project, a Kellogg Honors College engineering student decided to work on a campus wide CPP water education research project that included 600 subjects. The project was completed as an Honor's capstone project. Results are in preparation for publication.

Challenges to implement the project as a permanent part of the curriculum:

1) Adoption of the community interaction and public education research project would require including the IRB Collaborative Institutional Training Initiative (CITI) exercises, the protocol and survey preparation, and the submission to the CPP IRB as part of the curriculum. While these exercises are important, there is not enough time in the existing technical curriculum to include the entire new required curriculum. A possible solution to this problem would be to create a CE 499 Engineering Elective course that has CE 431 L as pre-requisite

Acknowledgments

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enrolled in the CE 431 Lab for their hard work and their passion to educate others regarding water issues in Southern California.

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Orientation to Engineering Education through applying "Puzzles Principles"

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Abstract

In this paper a review of engineering programs was conducted in terms of curriculum building and then application of the technique of "Puzzles Principles", developed by the author, was proposed which could be incorporated in the design of curriculums for effective engineering teaching at the onset. The concept of Puzzles Principles and its application can show how appropriately engineering education can be planned and how the requirements suggested by the Engineer of 2020 can be implemented in a "First Year Experience" type courses. An example of the application is provided to properly show the process of learning through re-engineering a product by showing the correlated possible scientific and engineering learning matters affiliated with the product design, testing , manufacturing and evaluations.

Introduction

Engineering education traditionally has been much segmented consisting of many courses being taught as independent subjects. It is typically divided into core, electives, support courses and General Education categories. In many instances a student spends the first two years taking support and general education courses and will not be introduced to an engineering course until the junior year. This is especially true when students attend Junior Colleges to prepare themselves for a four year university. Thus almost fifty percent of a new engineering student's college life is associated with diverse courses with none or little mention of any engineering application. Assuming that a student enters as a freshman to a university, they could possibly be exposed to an orientation course or an introduction course to their field. These courses are designed mostly to be a survey of the future courses that the student works through until they graduate and are referred to as an engineer. Again in most cases reasons of why those courses or the subject matters are important are not mentioned. Students assume that the faculty knows best and they help them eventually understand what is expected of an engineer. It could be said that the best possible scenario could be that an engineering student comes from a family of engineers who can inform him/her about their jobs and responsibilities.

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Once their education starts, there are times that a course is selected or defined as a prerequisite for other courses without genuine relation between courses or even minimal mention of relationships to others. Worse, review of programs has shown that often courses are taught without even mentioning their interactions with specific programs. If we are shaping and developing the engineer of 2020, then we have to change from the segmented teaching, look at the curriculum more from a "Systems" point of view and clearly show the interactions of courses and interrelations of them as they are being taught. This means that while the professor is lecturing a subject, he/she has to be relating it to the next course, show why previous courses were pre-requisites, and then show how the subject is used by a professional engineer at job sites.

Additionally, to enhance the linkage of courses, and teaching engineering in general, the author believes that students should be looked at more as a whole person, capable of higher cognitive skills that we might currently expect from them. Enhancing wisdom should be considered as we improve their intelligence to prepare them to be better product and process designers. Students are not to be looked at as robots, taking notes, listening, reading books and memorizing them and then show their intelligence by answering exam questions. Enhancing wisdom should be considered as we improve their intelligence. Of course this is of special importance in a capstone course where if it is correctly designed, it should incorporate the essence of their education in engineering, and not only one or two subjects. It is the author's belief that an orientation course should also contain an element that improves the wisdom and the sense of creativity of a freshman engineering course.

Finally engineering is a profession just like those in medical or legal fields. Television and films have clearly defined what such learned people do and students of such fields understand why any topic on their curriculum helps them in becoming better professionals. Other than MacGyver there has not been any other public visual presentation of how application of engineering principles helps the everyday lives of people. An engineering student should fall in love with the filed at the orientation course by fully learning about subjects that would lead him to have the required skills. A typical general education course or even a support course such as math would not give the person the thirst and the desire to learn about engineering. Don't medical students start with dissecting cadavers to learn about the human body? Why not do the same for our freshman engineering student? How about allowing them to dissect a product or a process and then learn about engineering design and evaluation? Disconnect assembled parts that are bolted, welded or crimped to know why one could be better and where one method of joining is used.

Starting an engineering program for college freshmen is mostly filled with uncertainty. Some possibly have heard of what they are supposed to do and others have no idea, just that it sounds good to be engineers. Civil engineers build roads, Mechanicals design products,. but how does triple integrals help them with roads, products, computers, etc. Universities design curriculum

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for engineering programs, identify pre-requisites, co-requisites, General Education , support classes, and all to build a foundation for engineering education. To a freshman, the foundation hardly shows any correlation with the final goal of becoming a designer of products and processes. The medical school curriculum and the law school curriculum fully support their education and it is hard to question why a course in biology or chemistry is needed for a medical school student. However, where and why linear algebra is used for design of a healthcare facility could be a legitimate question for a freshman. It is time to re-engineer the engineering education to ensure that an engineering student fully realizes the importance of learning every course and know the relationship of pre-requisites and the sequential course design. Figure 1 shows an example of a typical homework in an engineering course. A freshman could fail to see the application of wisdom and creativity in such assignments. In engineering orientation courses most of the time is spent on briefly explaining what courses are ahead of the students. In most programs students however never see any engineering until the junior year. Even if they see the freshman and sophomore courses in engineering, they are at the introductory level and boring for a person who imagined that they are product designers when they have to sit in class and take triple integrals. The main reason seems to be that learned and educated engineers have designed courses for themselves rather than for young inexperienced individuals who “think” that they know what is engineering.

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A machined shaft shown below is supported by two deep-groove ball bearings and transmits a torque of 100 N.m between gears X (80 teeth) and Y (60 teeth). Both gears have a pressure angle of 20° and a module of 2 and their contact to their mating gear is at 90° to each other as shown. Assume the gears are loaded midway across the face width. The shaft operates at a steady speed and is made from AISI 1095 steel which was quench & tempered at 650°C.

- Determine applied gear forces and the reactions at the bearings.
- Draw the shear, moment and torque diagrams for the shaft.
- Determine the fatigue factor of safety at location A using the ASME Elliptic criteria with a 99% reliability.
  Check 1st cycle yielding at location A.

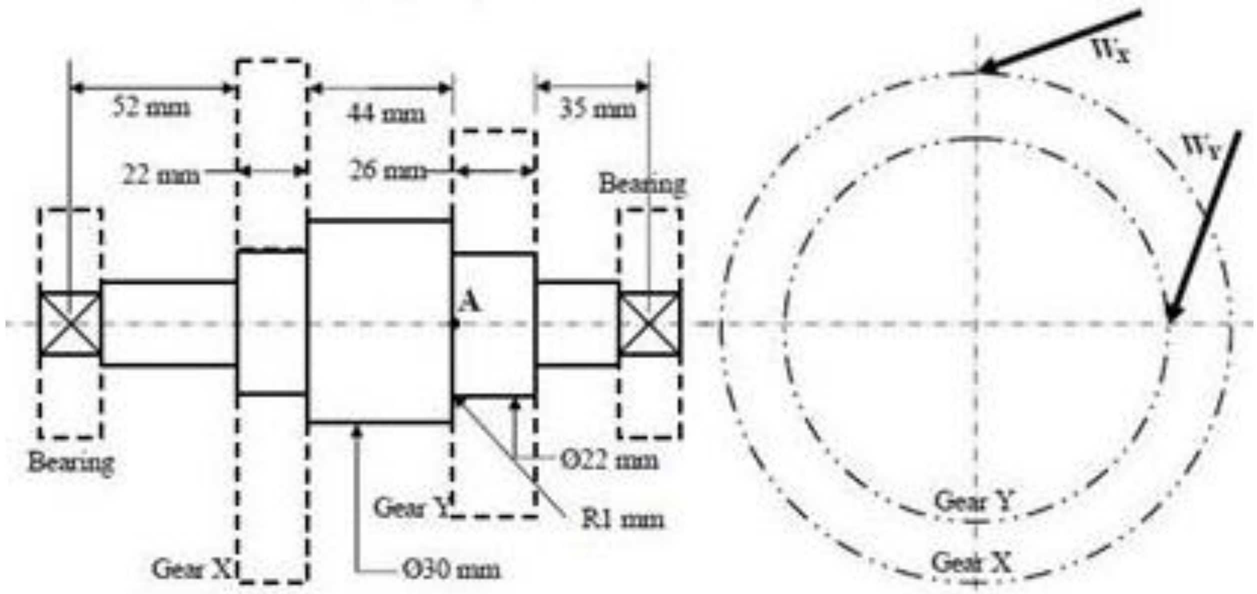

Figure 1: A typical assignment in an engineering course

Based on the author's review of many engineering curriculums the typical elements of most programs in higher education consist of:

- Flood with Information
- Combine with Technology
- Provide Diverse Subjects
- Make a Salad of Stuff

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- No mention of Wisdom
- Use artificial intelligence
- No mention of Natural Intelligence
- Produce Highly Skilled Robots

The review of the National Academy of Sciences Recommendations for Engineer of 2020 shows that:

- In developing curricula, students should be introduced to the "Essence" of engineering early
- Engineering educators should introduce interdisciplinary learning in undergrad. Teaching
- As well as delivering content, engineering schools must teach how to learn
- Engineers of 2020 should know when and how to incorporate social elements at work
- Case studies approach is recommended for undergrad curricula
- Reduce the period between achieving the "Program Objective" and the "Student Learning Objective"
- Enable them to see the big picture in each and every course

Thus to prepare a better engineer from the onset, it is the belief of the author that an orientation to engineering course should be designed based on the following criteria:

a- An engineer is a creative, intelligent and wise person. Assure that the learning elements lead to improving such traits
b- The curriculum review in such classes could work better once reasons for subjects studied are understood by students
c- Dissection and re-engineering of product should be a necessary element in the curricula
d- Puzzles Principles (defined next) is applied to design the syllabi of such courses

Puzzles Principles

Based on the above arguments and more, the author has developed the Puzzles Principles. To understand the concept, the reader is asked to imagine a jigsaw puzzle (figure 2). A jigsaw puzzle consists of many pieces that make up a big picture, just like courses we put in a curriculum for an engineering program. When trying to assemble the puzzle, one looks at the main scene, visually divides the scene into sections (i.e. for a natural scene you could have trees, sky, water, etc.), groups the pieces in sub groups (i.e. borders have straight edges, pieces that look like they belong to a body of water, etc.), and although the pieces could be connected in

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subgroups, the relationship between the big picture, the segments and the pieces are still clear to ones mind. It seems to be essential that a freshman level student should also be able to see the big picture from day one and visualize the relationship between the courses (puzzle pieces) and any main subjects being taught (i.e. optimization) and also the big picture (i.e. any major in Engineering)? This visualization requires wisdom, creativity and intelligence, all three are the major components of the Puzzles Principles.

As the second phase of application of Puzzles Principles, the author proposes a process of redesigning an introductory course where real life puzzles are introduced (the big picture), main problems are identified (a sub-scene), and the need of the specific subject of study is clearly defined (each piece of the puzzle), and then show why the puzzle piece or the course is needed for a specific part of the curriculum (Sr., Jr, etc.)., and without this piece the engineering education is incomplete.

Furthermore, still keeping track of the concept of puzzles, engineering courses should be developed so that students use their wisdom to mainly define puzzles, and less emphasis on solving them (where they had already learned at previous stages). For real life industry problems, professionals are always faced with puzzles and not homework problems. "How" should one solve the puzzle and "What" date to gather is more relevant than discussing solving situations that computer software can actually solve problems faster and the student is merely a data entry clerk. This basically means that wisdom in decision making should be more emphasized than just the use of intelligence to solve them. Here effective approach to problem definition is emphasized (looking at the big picture), then how optimally big scenes could be divided into smaller sub-scenes, and then how to find the right pieces that belong to the sub-scenes could be emphasized. Once this activity is performed, not only solutions could be provided more efficiently, the cognitive skills used in engineering decision making is enhanced leading to better and more creative engineering designs of products and processes.

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Figure 2: A Jigsaw Puzzle

The application of Puzzles Principles was developed as cases for the capstone course in Industrial and Manufacturing Engineering department at Cal Poly Pomona. In such cases scenarios were developed based on real industry situations and data (real or not) was provided without mentioning any reasons or questions. Students working in teams compete against each other to discover the main reason behind the case (the puzzle), provide problem statements, search and justify the best tools for problem solving, identify and use the right data to solve problems, and provide solution for the puzzle, the main case, and not just the sub problems. All of this is simulated through a real scenario for which the recommendations should be provided within a limited time (usually a week), and just like real life only one team is chosen by the customer (the professor) as having the right solution meeting the customer's expectation. However, unlike as in real life, the losing teams don't fail, but they receive lower scores. Although a very rigorous and time consuming course, for the last several years of applying this technique, students have praised the course as the most valuable experience in their undergraduate education. The feedback from the Course Evaluations provided at the end of each term showed learning achievement at a very high level. At the exit interview almost all students praised the course as the one that gave them the confidence they needed to enter the job market, and lastly for Program Outcome assessment alumni expressed that although they may have used some of the subjects that they learned at school in their various jobs, they have mostly benefited

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from the experience of tackling the puzzles of the capstone course when they were faced with the day to day puzzles that they get exposed to in the industry.

Applying the second phase of application of Puzzles Principles, the author has reviewed and redesigned the entire undergraduate industrial and manufacturing engineering curriculum as a systems analyst to ensure that the links became apparent, and in each course real life puzzles are introduced (the big picture), main problems are identified (a sub-scene), and the need of the specific subject is clearly defined (each piece of the puzzle), and then why the puzzle piece or the course is needed for a specific part of the curriculum (Sr., Jr, etc.) is shown. Figure 3 shows the procedural stages of the puzzles principles.

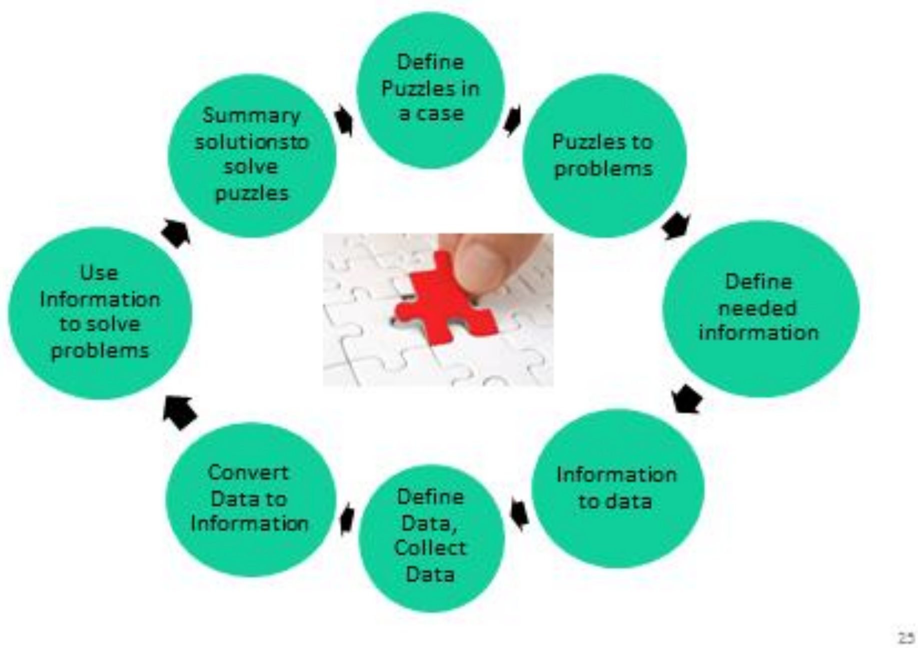

Figure 3: Puzzles Principles Procedural Stages

For the engineering orientation course the curriculum design should include the application of Puzzles Principles through stepwise systematic re-engineering of engineering design. In order to do so the author proposes the implementation of learning practices to assure the blended skillsets as described below are developed by the freshmen to the point that they realize their ability as they progress to the conclusion of the course.

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The skillsets chosen for an engineer are those that are clearly identified by all stakeholders in the education of such engineers. The stakeholders include not only the students themselves, but the future employers, the professors and the university community, and the society as a whole. This is true especially for state universities that are partially supported by the public tax and industry support.

A complete set of blended skillsets are as follows:

- **Understanding Case Formats**
- Quantitative Skills
- Oral and Written Communication Skills
- Critical Thinking
- **Creativity**
- Problem Solving
- Ethical Decision Making
- Information Literacy
- **Team Working Skills**
- **Self-Direction**
- **Leadership**
- **Lifetime learning**
- **Competitiveness** to excel

The Puzzles Principles assumes the actual activities involved in its applications are done at the various stages of education of an engineering student as soon below:

- **Senior Level**: Identify Puzzles and Solve (Apply Wisdom and Intelligence): What is the Situation? Who are involved? What are the basic problems? What subjects from the curricula should be used? How should I solve them? Which techniques should I use? What are the constraints? What types of information do I need? What data do I need? What makes my recommendations better than others? How do I present it? Who do I present it to? How were the Prerequisites, GE, Core, Breath subjects incorporated?

- **Junior Level**: Solve Puzzled Problems using gathered information (Learn Wisdom, apply Intelligence): Why I am losing money? What could have improved Obama's Health Plan? Do I have enough inventory? Is 2 + 2 good? How were the Prerequisites, GE, Core, Breath classes incorporated?

- **Sophomore Level:** Learn about information, Analyze Data, Convert to Information, Solve Problems, Learn about Puzzles (Learn wisdom and Intelligence): How hot is a typical Jacuzzi, Is this a Shakespearian style of writing? What happens that you end up

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with a whip lash after an accident? Why lemon tastes tart? How were the Prerequisites incorporated?

- **Freshman Level:** Visualize yourself as a wise and intelligent professional after graduation, Gather Data, Analyze Basic Data, Learn basic data-Information conversion, Solve basic Puzzles, Learn about how to become wiser and more intelligent by participating in a re-engineering of a puzzle solved.

The following specific procedure is proposed to be incorporated in an orientation to engineering course:

1- Choose a puzzle from a real life situation solved and reviewed by engineering professionals that was reviewed by upper classmen. Example: The management at a luxurious hotel are unhappy seeing housekeeping carts in the hallways and they believe such items should be invisible to their guests, however the carts are needed for resupplying and changing room products

2- Choose a product that was a major contributor to the puzzle: The cart

3- Who are involved: Guests, Management, Housekeepers, Maintenance, Buyers

4- How are they affected: Housekeepers have to push carts, guests see obstacles, and maintenance personnel repair them.

5- Basic problem: Although necessary for transportation of items to, they are heavy, bulky, hard to move causing back problems, esthetically not pleasing …

6- How are they Designed and manufactured: Take a part, identify the material used for manufacture and assembly, review the design, identify the design criteria and strategy (Biomimicry, Total Design,..), identify the manufacturing and assembly processes (Design for Maintainability, Design for Manufacturing or assembly), identify other options,..; What is the cost; Where is the product purchased from? Who makes them?

7- Identify the subjects and courses in the curricula applied to the design and evaluations: Wheels go over the floor carpet for which we should know the coefficient of friction (mechanical engineering, civil engineering, materials engineering); The height of the cart should be less than the height of the housekeepers, the weight should be so that it would not cause joint problems (human engineering, anthropometry, biomechanics);…In order to biomechanically analyze the situation one needs to know Statics and Dynamics,…. To solve a statics problem one needs to apply physics, and math,…; Cost accounting and

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engineering economic analysis to justify costs;..; Quality and reliability of product performance affects the costs (SPC, Statistical Analysis) needing mathematical analysis;..

8- Where and how to collect data for analysis: Use Force gages, time studies, contact material producers, carpet manufacturers, wheel manufacturers, weight of linen, strength of housekeepers,…; All such data gathering are shown in engineering laboratories (Mechanical, Material, Biomechanics, anthropometric tables),..

As shown in the above steps, students get fully engaged in all aspects of a real life puzzling situation from ground zero, at the freshman level, where an engineered product is evaluated and redesigned and using their creativity and wisdom identify the importance of all the puzzle pieces involved in completing the entire picture, their course of study in engineering.

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Presenting Concepts of Big Data in Information Technology Curricula

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Abstract

In the information technology industry today, there has been significant growth in rapid data mining and analytics applications that process very large volumes of data. This calls for adopting Big Data technology in the Information Technology curricula to prepare todays engineer for the industry. This requires aligning existing curriculum to cover topics such as distributed systems, parallel processing and coordination, fault-tolerance, scheduling and load balancing. In this paper we identify core concepts to be include in new courses. We also look at a typical Information Technology curriculum and present an approach of redesigning it to address the need. It identifies ways to extend, modify or replace existing course components to introduce these concepts in both four-year undergraduate and graduate programs.

Introduction

The convergences of intelligent devices, social networking, pervasive broadband communication, and analytics is ushering a new economic era that is redefining relationships among producers, distributors and consumers of goods and services. The key features of the data are its very large volume, high speed processing and the diversity. Recent articles such as [1] emphasizes the role of Big Data technologies in innovation that is leading us to an "intelligent" economy of smart cars, smart buildings, better healthcare, law enforcement and education, productivity gains in economy and new and efficient ways of interacting with customers.

The requirements for handling structured data with fixed schema, as well as unstructured data with no fixed schema, and theoretically unlimited volume and velocity of data has prompted the development of the so called Big Data technologies. Most of these are in the open source and has been spurring rapid adoption by the industry. Although their availability is easy these technologies are based on advanced Information Technology concepts such as service-oriented architecture, distributed parallel processing, cluster administration, performance monitoring and interoperability.

The goal of this paper is to identify the core and optional needs for the academic preparation for a graduate in Information Technology program, compare it with typical curriculum and suggest how any gap can be filled in. We begin with a brief highlight of the computing curricula 2008 from Association of Computing Machineries (ACM) for Information Technology, Information Science and Computer Science and the

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Accreditation Board in Engineering and Technology (ABET). Then we identify topics in the ACM curriculum for Information Technology that are relevant to Big Data concepts and map them to a specific undergraduate program. We also present the courses in a masters level program in Information Technology and examine the relevance of these courses to Big Data education. present a short review of the curriculum of Information Technology in a typical four-year undergraduate and graduate levels today. We then identify courses that are relevant to concepts in Big Data. We present the current scope of the Big Data industry and the core concepts of Big Data technology. This is then followed by a plan for adoption of the Big Data concepts in to existing courses in Information Technology illustrated using the typical example used earlier. In general, we believe similar approach can be used for programs in Information Technology in other academic institutions.

Information Technology Curricula

Academic programs in Computer Science and Engineering, Information Systems, Information Technology share some core concepts. While the first focuses mainly in the design, development, maintenance and architecting digital computer systems, both hardware and software. The second deals with information systems composed of diverse information sub-systems including human operators and automatic processors such as digital computers or other devices to support business environments. They look at interfaces of computing sub-systems and emphasis the user and organizational aspects. The third is in-between the first and the second in their involvement in dealing with both business and the technology, although more emphasis is on development.

The special interest group on IT education (SIGITE) of ACM created accreditation criteria for the Accreditation Board for Engineering and Technology (ABET), which is the main US accreditation agency for programs in computing, engineering, engineering technology and applied sciences [2]. Also, they formed a curriculum committee, SIGITE Curriculum Committee, to develop a model curriculum for IT. The goal was to ensure that the curriculum can be accredited and it was developed in the context of the ACM Computing Curricula project [3]. Also, the curriculum must reflect the relationship of IT to other computing disciplines as they depend on materials covered in other computing disciplines. The curriculum must reflect the aspects that set IT apart from other computing disciplines. The overview report of the Computing Curricula 2005 was augmented as necessary and organized into a form acceptable to the Computing Curricula Series, which is a guideline for four-year undergraduate degree programs in IT from ACM and IEEE in 2008.

IT as an academic discipline is concerned with issues related to advocating for users and meeting their needs within an organizational and societal context through the selection, creation, application, integration and administration of computing technologies.

The program outcome in the ABET Course Advisory Committee (CAC) accreditation criteria is an important input in the development of the IT model curriculum. Among others, the CAC 2005 Overview Report lists the following:

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- Ability to design, implement, and evaluate a computer-based system, process, component or program to meet desired needs
- Ability to analyze the impact of computing on individuals, organizations, and society, including ethical, legal, security and global policy issues
- Recognition of the need for an ability to engage in continuing professional development
- Ability to use current techniques, skills, and tools necessary for computing practices

Curriculum and course mapping

The following table identifies courses that are relevant to BigData.

Tech topics cited in the ACM CC 2008	Relevance in BigData context	Course Map (90:_) (see Table 2 for titles of course numbers)
The World Wide Web and its applications	Common Web GUI for BigData service management portal	231, 238, 247, 248, 291, 302
Networking technologies, particularly those based on TCP/IP	Networking in clusters, socket level, application level, load estimation, supporting distributed services	461, 462, 464
Systems administration and maintenance	Cluster administration, service administration and management, troubleshooting	311,312, 313, 319, 321
Graphics and multimedia	Understanding distributed graphics and multimedia application in BigData environment	230, 267, 268, 311, 313, *
Web systems and technologies	Techniques used in Web server systems useful in design, development of BigData services that are efficient	91.113, 250
Service-oriented architecture	Recognizing service-oriented architectural concepts in understanding BigData products	311, 250, 91.113, 303, 305, *
E-commerce technologies	Understanding capability scope of BigData	250
Client-server technologies	Understanding role in design of BigData products	311, 313
Interoperability	Understanding role of message level interoperability, products such as Apache Thrift, Gueva(?) and their role in BigData	303, 311, 313, *
Technology integration and deployment	Recognizing role of integration and deployment of BigData services	303, 311, 313, 450, 453, 455, *
Object-oriented even-driven programming	Recognizing role of object-oriented and event driven programming in the context of BigData	225, 268, 301, 303
Sophisticated application programmer interfaces (APIs)	Recognizing APIs used in developing applications that uses BigData framework and products	301, 303, 360, *
Human-computer interaction	Role of debug and application logs, system and service performance monitoring tools, tools for administration and management of services in the BigData context	311, 313, 303, 360, *
Security	Issues of security at different levels and their benefits/limitations in BigData context	385, 457

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Application domains	Understanding of distributed parallel programming (MapReduce, Distributed File Systems, Index structures, memory resident objects, load balancing, workload distribution, coordinations and scheduling.	220, 224, 225, 306, 308, 247, 268, 269, 270, 271, 297, 301, 302, 303, 305, 459

Table 1: Relevance to Big Data

Table 2 is the list of undergraduate courses in Information Technology offered by the University of Massassuchetts, Lowell http://www.continuinged.uml.edu/degrees/bs_informationtechnology.cfm). The third column in Table 1 gives a rough mapping of these courses to the topics. The following table lists the courses.

Elective course (10 to choose)	
90.220 Visual Basic	90.306 Introduction to XML
90.224 Advanced Visual Basic	90.308 Agile Software Development with Java
90.225 Survey of Programming Languages	90.311 Introduction to the Linux/UNIX Operating System
90.230 Introduction to Multimedia	90.312 Shell Scripting
90.231 Graphics for Multimedia and the World Wide Web	90.313 Linux/Unix Internals Overview
90.232 Desktop Video Production	90.319 Introduction to Linux
90.238 Website Development: Adobe Dreamweaver	90.321 Linux/UNIX System Administration
90.247 Web Authoring: Flash	90.346 Digital Media Delivery
90.248 Website Database Implementation	90.360 Introduction to Data Structures
90.250 E-Commerce on the Web	90.364 Problem Solving with C
90.267 C Programming	90.385 Introduction to Information Security
90.268 C++ Programming	90.450 Database Administration I: Introduction to Oracle 11g
90269 Advanced C++	90.453 Database Administration II: Advanced Oracle 11g
90.270 Visual C++.NET	90.455 Database Administration III: Oracle 11g projects
90.271 C# Programming	90.457 Network Security
90.291 Introduction to DHTML	90.459 PL/SQL I: Introduction to Oracle 11g PL/SQL
90.297 Introduction to Java Programming	90.461 LAN/WAN Technologies
90.301 JAVA Programming	90.462 TCP/IP and Network Architecture
90.302 JavaScript	90.464 Network Management
90.303 Advanced Java Programming	90.467 Relational Database Concepts
90.305 Survey of Perl/Python/PHP	91.113 Exploring the Internet

Table 2: Courses at UM Lowell

The University of Massachusetts Lowell Bachelor of Science degree in Information Technology is available as online, in campus or as a mix of online and in campus courses.

Masters level degree programs

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The http://www.thebestschools.org/blog/2012/10/29/20-online-master-information-technology-it-degree-programs/ lists universities that offer online masters level degree programs in IT. Generally, computing or business schools offer these programs. We examine the Masters program in IT at New Jersey Institute of Technology. To understand the flavor of the masters program first observe the range of specializations offered at the BS level by the department of information technology http://it.njit.edu/academics/graduate/BSITBrochure.pdf . These are "Systems integration, administration, design, deployment and management of computing and telecommunication resources and services", "Security and information assurance, ethical hacking, intrusion detection", "Multi-media, graphics design, entertainment technology, and animation", "Game development including options in programming, art and design", "Management information systems and accounting", "Criminal justice and law, computer forensics". They offer the MS degree in IT Administration and Security.

The curriculum is given in http://it.njit.edu/academics/graduate/index.php. The objective of this program to prepare students for database, network, security and web services administrators, enterprise application administrators and as IT administration managers. The students are expected to be a mix of working professionals and graduates of their undergraduate computing programs most of who take the network and security concentrations.

The required (in bold) and elective courses in the MS AS course at NJIT are as follows:

IT 620 Wireless Network Security & Administration	CS 633 Distributed Systems
IT 635 Database Administration	CS 652 Computer Networks- Architectures, Protocols and Standards
IT 610 System Administration	IS 631 Enterprise Database Management
CS 656 Internet and Higher Layer Protocols	IS 677 Information System Principles
CS 696 Network Management and Security	IS 679 Management of Computer and Information Systems
CS 640 Web and Domain Server Administration	IS 680 Information Systems Auditing
CS 631 Data Management System Design	IS 681 Information Systems Auditing
CS 632 Advanced Database System Design	ECE 645 Wireless Networks
CS 697 Principles of Broadband Networks	HRM 601 Organizational Behavior

Table 3: NJIT Masters courses

The Big Data

Big Data means processing of large volumes of data, often in semi-real time, where data can be of different types. Over two billion people have access to the Internet today. This results in the accumulation of very large amount of data, which can be a gold mine of valuable information. With large volume of data one is interested in scalability or the capability of linearly proportional processing time with data size.

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Big Data industry

A brief survey of the tremendous value in processing of ever-increasing volumes of data at high speed and unstructured format can be found in [4]. There are many other literatures on the role of data analytics in the context of Volume, Velocity and Variety [5, 6].

Essential concepts in Big Data

Todays Big Data industry is credited to the work of Google, Yahoo and others during 2001-3. It derived from the idea of high performance computing using cluster of commodity machines. The technical foundations for this was multi-processing on a distributed computing environment built using cluster of commodity machines. This is often called – horizontal scaling. Scaling an application is the ability of maintaining processing time to be more or less constant with increasing data volume as long as one is allowed to increase the number of commodity machines proportionately.

The applications that were of interest were processing ever-increasing log files, mostly generated by automated interactions of software systems such as search, web logs, web documents. These applications proliferated into the area of data mining and machine learning for building intelligent alert, notification, and business intelligence and decision support systems. The latter application scenarios and use cases nurtured the Big Data ecosystem and cloud computing. Initiated by companies such as Amazon, eBay and others this just spread in multiple ways.

In addition to cluster of computers and distributed parallel processing with a service oriented approach data processing support for structured and unstructured (with no fixed schema) were core technologies associated with data mining and analytics support. Today, data science application is closely associated with Big Data processing.

The core topics related to Big Data are the following:

1. Cluster of commodity machines
2. Distributed parallel processing – speed and scalability
3. Structured and unstructured data
4. Distributed coordination service
5. Redundancy and fault-tolerance

One approach can be to revise and adopt existing courses in Information Technology to include Big Data concepts. Another approach can be to replace and add one or more new course, depending on the goal of the level of preparation of students, that covers the topics listed above.

New Course(s)

The contents of one or more new courses are based on the need of covering the cores concepts presented above. The contents are described below.
<u>Topic 1: Computer Cluster</u>

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The idea of using multiple commodity computers, connected via local area network, originated with the work of building a cheap super-computer. The essential goal was to set up an affordable but useful hardware/software platform for distributed parallel processing that can support high performance computing based on distributed memory parallel processing. It was clear that a key bottleneck in such a set up is the inter-processor communication capability.

Topic 2: Parallel and Distributed Processing – speed and scalability

The Big Data uses a highly popular and simple model for parallel processing. This is known as Map Reduce [7]. A basic concept is functional programming, in which data is available as a key-value pair. The map and reduce functions transform key-values into key-values. The input data (considered a key-value pair) is converted to a new key-value pair by a map function. The reduce function can aggregate key-value pairs by the key value.

MapReduce (MR) framework was designed to address the challenges of large-scale computing in the context of long-running batch jobs. The success of MR led to a wide range of third-party implementations, notably the open-source Hadoop [8] and a number of hybrid systems that combine parallel DBMS with MR, offered by vendors like Aster, Cloudera, Greenplum and Vertica. Hadoop 2.x contains Yarn, which is a general-purpose resource management system for the underlying cluster of commodity system.

Topic 3: Structured and Unstructured data

The very nature of log data is unstructured and varied. Consequently one requirement for Big Data has been the ability to process data in different formats, which may not be known beforehand. The key-value pair data structure is amenable to flexible formatting. Structured data is typically processed as tables with schema in relational database systems (RDBMS). High-speed data operations can be performed in parallel RDBMS. In distributed systems programming languages and messages use a nested representation (such as a tree). Normalizing or recombining these at Web scale is usually very costly. Note the complementary nature of MR and parallel DBMSs [9].

In processing unstructured data a flexible scheme is needed, as the format of data is not known beforehand. The granular key-value data format is used to create dynamic schema on the fly. This is supported via a column oriented table data structure known as Big Table, which is also amenable to distributed data allocation and processing. Examples of usage scenarios include – analysis of crawled web documents, spam analysis, debugging of map tiles on Google Maps, tablet migrations in managed Big Table instances, results of tests run on distributed build system, disk I/O statistics for hundreds of thousands of disks, resource monitoring for jobs run in data centers etc. at Google. The column oriented data structure can be efficiently partitioned and redistributed across the nodes of a cluster. Columnar storage format is supported by many data processing tools such as MR, Sawzall [10], FlumeJava [11].

Data in a Big Data framework resides in a distributed file system modeled after Google File System developed at Google [12] and Big Table. Data is structured similar to a serving tree of a distributed search engine. The machines in a cluster hosts sub trees in different machines. A query gets pushed down the tree to the machines hosting the sub trees for computing the results. The results are then aggregated in parallel. This is a well-known parallel processing paradigm.

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Dremel [13] can execute many queries that run faster than running sequences of Map Reduce (MR) jobs. Dremel is used in conjunction with MR to analyze outputs of MR pipelines or rapidly prototype larger computations. Unlike Pig [14] or Hive [15] it does not execute queries as MR jobs.

In Big Data storage technology key design goal is to meet reliability and scaling. The Amazon Simple Storage System or S3 is based on Dynamo [16] with a tight control over the tradeoffs between availability, consistency, cost-effectiveness and performance. Actual production performance of Dynamo supports 3 million checkouts of purchase portal of Amazon. Different techniques have been combined to provide a single highly available system. It is an eventually consistent storage system that can support demanding applications.

Topic 4: Distributed Coordination Service
This distributed service is fault-tolerant and allows a registry service where state information can be preserved. This allows a service to restart and reinitialized by accessing the state information stored in the registry. The content should cover elements of distributed coordination services that include leader election using quorums, use of technology such as zookeeper [17] and related matters.

Topic 5: Redundancy and fault-tolerance
Scalability, fault-tolarence and availability in Dynamo is implemented through data partitions and replications using consistent hashing, object versioning. Consistency among replicas during updates is maintained by a quorum-like technique and a decentralized replica synchronization protocol. Gossip based distributed failure detection and membership protocol.

Curriculum adoption

A number of companies such as Cloudera, Hortonworks, MapR and others offer specialized trainings on various Big Data products, most of which are open source, and technologies. Scores of online documentations and tutorials are available as well. Unfortunately these materials are not suitable for inclusion in a curriculum directly. Utmost care needs to be given to select appropriate context and material when existing courses are modified or extended to include such materials. Below we identify a set technology, which in our opinion forms the base that demonstrates the core concepts of Big Data.

Concepts/Technology	Possible target course for modification
Distributed File System	90.360 Introduction to Data Structures 90.311 Introduction to the Linux/UNIX Operating System CS 633 Distributed Systems
Parallel processing (Map Reduce, Query processing on column-stripped nested data)	90.360 Introduction to Data Structures 90.250 E-Commerce on the Web 90.303 Advanced Java Programming
Big Data eco-system (Hadoop, Pig, Hive…)	90.467 Relational Database Concepts

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Distributed Coordination	90.360 Introduction to Data Structures 90.303 Advanced Java Programming
Cloud computing technology (SaaS, PaaS, IaaS)	90.250 E-Commerce on the Web 90.311 Introduction to the Linux/UNIX Operating System
Cluster administration (chef, puppet), monitoring and tuning	90.311 Introduction to the Linux/UNIX Operating System 90.461 LAN/WAN Technologies 90.462 TCP/IP and Network Architecture 90.464 Network Management **IT 610 System Administration** **CS 696 Network Management and Security** CS 632 Advanced Database System Design
Big Table and column oriented data structure processing	90.360 Introduction to Data Structures 90.467 Relational Database Concepts 90.303 Advanced Java Programming
Object oriented database for indexed key-value storage	90.360 Introduction to Data Structures 90.467 Relational Database Concepts
Service oriented design, installation and configuration, interoperability	90.250 E-Commerce on the Web 90.311 Introduction to the Linux/UNIX Operating System 90.462 TCP/IP and Network Architecture 90.303 Advanced Java Programming

Table 4: Existing Courses to modify to adoption of Big Data Concepts

For distributed file system, we can introduce topics on data structures that allow concurrent operations on data. Benchmarks can be introduced in this context. Replication to preserve data quality despite faulty hardware and achieve fast response times in presence of stragglers. Resource scheduling for CPU, rescheduling slow or faulty process and load balance are some related topics.
For a master level course, the subject titled distributed systems is often part of existing concurrency. This course can provide the context of most basic concepts pertinent to the Big Data technology. In masters level we can cover the topic of data analytics at scale that needs a high degree of parallelism.

Parallel processing can be introduced in the data structure course as well as in advanced Java programming course. Functional programming, data parallel programming and Map Reduce as functional programming paradigm, parallel query processing where sub-queries are evaluated in parallel followed by aggregation by combining the result are some of the topics that can be covered. Data structure can be a complementary course in which column stripping and data splitting to support scalability and data parallel mode of computation. Construction of query processing engines for nested data records in columnar representation of nested data and its platform neutral nature together with serialization is a related topic that can be part of the data structure course.

As part of the combination of programming and data structure courses we can include the topic of code generation tools, bindings for programming languages such as C++ or Java. In addition, topics such as cross-language interoperability – using a standard binary on-the-wire

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representation of records in which field values are laid out sequentially as they occur in the record can be included. Also, assembling columnar representation to record for interoperation with MR and other data processing tools can be included.

Distributed coordination system can be included in advanced programming course in the context of concurrency. Products such as Zookeeper [17] can be included via lab exercises together with Java based programming. Cloud computing topics can be included in the E-commerce on the Web from a use case scenario. In this context both SaaS and PaaS can be introduced. IaaS can be introduced in the context of Linux/UNIX operating system. Cluster administration topics can be added in Linux/UNIX operating system. Associated topics can be covered in subjects on LAN/WAN, TCP/IP and Network Architecture and Network Management. Big Table topics can be included in Data Structures, relational database and advanced programming. Object oriented database can be covered in this context. Service oriented design; installation, configuration and interoperation can be covered in advanced programming, Linux/UNIX operating system

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PhiMap: an online platform for auditing introductory physics exercises along educational descriptors

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Abstract

We present an online platform called phiMap for auditing introductory physics exercises based on educational descriptors. Symbols, equations, exercises, and descriptors, which are linked through a relational database, can be visualized based on their distribution within a selection of exercises. Descriptors are specified along cognitive taxonomies and problem features relevant to education. We demonstrate how phiMap can be used to assess a selection of exercises in order to quickly and visually determine whether any educational descriptors are underrepresented, and add exercises that may mitigate such underrepresentation. We conclude by discussing how phiMap provides decision support for selecting physics exercises tailored to educational taxonomies in a rapid and collaborative manner.

Introduction

Proficiency in problem solving has long been a central objective for introductory science, technology, engineering, and math (STEM) courses. Beyond developing a knowledge base, such STEM courses should place focus on building the necessary skills for quantitative and qualitative problem solving. By identifying problems that support comprehension and expert-like thinking, educational taxonomies attempt to relate problems to the cognitive processes required for solving them[1,2]. Other research-based methods focus on problem features considered to support learning[3] (calculus-based vs. algebraic, quantitative vs. conceptual, etc.).

One method of identifying learning objectives is Bloom's taxonomy. An extension of this taxonomy to problem solving in introductory physics is called the Taxonomy of Introductory Physics Problems (TIPP)[4]. Such taxonomies classify problems through constructs that are primarily cognitive and likely foreign to most STEM instructors (e.g., knowledge retrieval, integration, meta-cognition). While such taxonomies can guide the design of STEM curricula, there is a lack of tools enabling instructors to efficiently gauge their representation within a specific selection of exercises. More problematic is that taxonomic constructs are prone to subjectivity and/or interpretation. To address these issues, we developed an online platform called phiMap, which is a database of physics symbols, equations, topics, and descriptors. By symbols, we mean physical quantities typically represented in an equation by letters, such as energy E or wavelength λ. Equations are linked collections of symbols. We adopt the view of a

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graph, where a symbol represents a node and co-occurrences in an equation represent edges between the nodes. Any particular selection of exercises then corresponds to a collection of subgraphs –be they linked or disjointed– within the database. Presently, exercises in phiMap are drawn from a textbook[5] used for introductory undergraduate physics courses.

For each exercise, education-based descriptors may be assigned at the granularity of the exercise, equation, and/or symbol. Descriptors are user-defined elements that are either fixed (such as a taxonomy of cognitive processes or a set of problem features) or free form (such as word tags). A given selection of exercises may be displayed or sorted along any combination of these descriptors. As an example, a descriptor could assign to each exercise a simple tag, such as "easy," "medium," or "difficult." Or, a descriptor could serve to assign a topic to each equation, such as "beat frequency" or "kinetic energy." As a more advanced example, descriptors could comprise an educational taxonomy, as we will show in following sections. Figure 1 summarizes the symbols, equations, exercises, and descriptors implemented in phiMap.

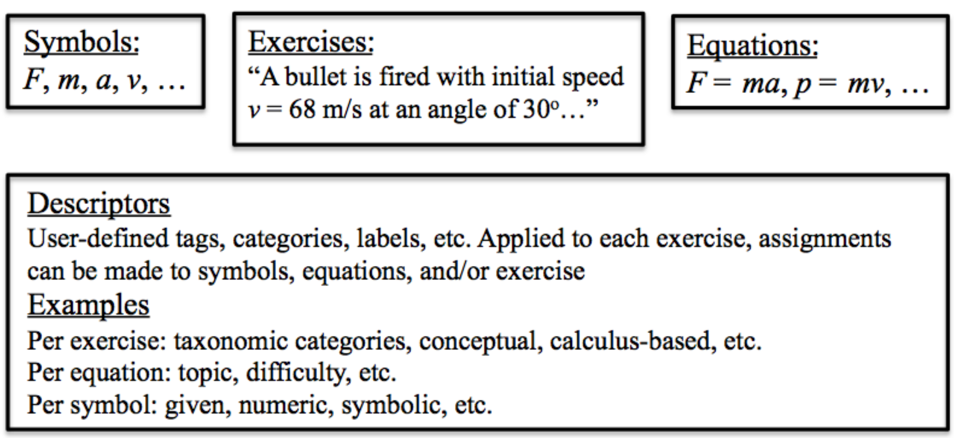

Figure 1: Overview of the different data elements implemented in phiMap.

As descriptors operate at different granularities, they allow for complex relationships within a set of exercises to be audited. Concretely, instructors may quickly view the distribution of symbols or equations associated with a set of exercises in terms of educational descriptors. Should any descriptor appear to be under- or overrepresented, the instructor can balance the corresponding selection by adding or removing exercises. In the following sections, we describe the phiMap architecture and illustrate how collections of physics exercises can be audited to improve their selection.

System architecture

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PhiMap is implemented in HTML5, Javascript, and CSS using a Python-based web application framework called Django. It can be accessed via any standard web browser, and output is visualized using the Javascript library Data Driven Documents (d3.js). The Django framework follows a Model-View-Controller (MVC) design pattern. In this MVC architecture, software is partitioned into three interconnected components consisting of models, views, and controllers. The model, which manages the data, is responsible for structuring data in a way that best captures the behavior of the application in terms of its domain problem. The view is responsible for the management of the output, and supports multiple representations and visualizations of the output and data. Visible elements are relayed through file templates that render the output through HTML, CSS, and Javascript. The controller translates input from the view into database queries, and converts any resulting output from the model into a format that can be redisplayed by the view.

In phiMap, models for symbols, equations, exercises, and descriptors are mapped to a SQLite relational database. Symbols correspond to physical quantities, such as F for force or a for acceleration. Symbols are defined by two fields: a label ("force"), and a standard Latin or Greek letter (such as F or λ). Since all symbols are rendered in mathematical notation when they are displayed in the browser, Greek letters and special characters are entered into the database using their LaTeX markup ("\alpha", "f_{0}", etc.). Symbols may be displayed either by their label ("force") or their letter ("F").

Equations are defined by two fields: a label ("wave speed"), and a string representing LaTeX markup that is rendered by the browser ("v = \omega/k"). Individual symbols, which are related to equations in a many-to-many relationship through linking tables, are linked to the equation either when it is created or at a later time. When generating output for a selection of exercises, symbols and equations are joined through linking tables into a sub-graph specific to that selection.

Exercises are defined by three fields: a label, their text, and an optional figure. Because SQLite is a file-based database, images can be directly uploaded into phiMap when the exercise is created (or at a later time). Since images are limited only to formats displayed by modern web browsers, phiMap supports a wide range of image formats (PNG, JPG, GIF, etc.). Linking tables are used to join exercises with their relevant equations, which in turn serve to associate relevant symbols to each exercise. After a set of exercises has been selected, phiMap provides the instructor with immediate statistics regarding the overall representation of each equation and symbol in the set.

Descriptors are assigned per exercise through a web-based HTML form. Since a user login is required, phiMap keeps track of descriptor assignments made by different instructors. Linking

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tables are used to join descriptors to symbols, equations, and exercises, and distributions of these quantities are specified using HTML templates. Figure 2 illustrates the above database schema.

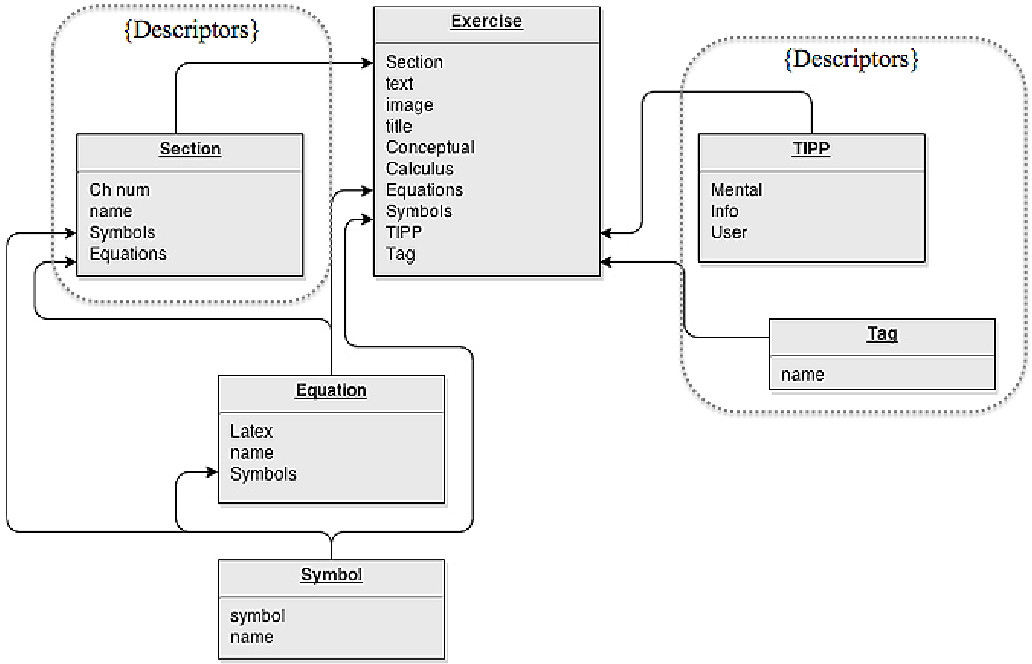

Figure 2: Database schema employed by phiMap. Any number of descriptor tables, such as the aforementioned TIPP, can be associated to the exercises.

Python controllers are responsible for turning user requests into proper database queries, then returning the results in a format used by templated HTML files for displaying visualizations. We use a popular Javascript library for data visualizations called Data-Drive Documents (D3), which displays a wide variety of data in the form of graphs, histograms, line plots, and interactive charts. MathJax is an open-source platform that performs typesetting of mathematical expressions written in LaTeX markup for any standard browser. We use MathJax to render symbols and equations in their mathematical notation. Users may choose to display symbols and equations by their labels or by their symbolic notation.

Descriptors organize symbols and equations by any user-defined topic, e.g., by weekly topics of a course. Figure 3 illustrates how equations and symbols are labeled with descriptors for each exercise. The resulting visualizations are displayed at any level of granularity, e.g., for any ordering of symbols, equations, exercises, or descriptors.

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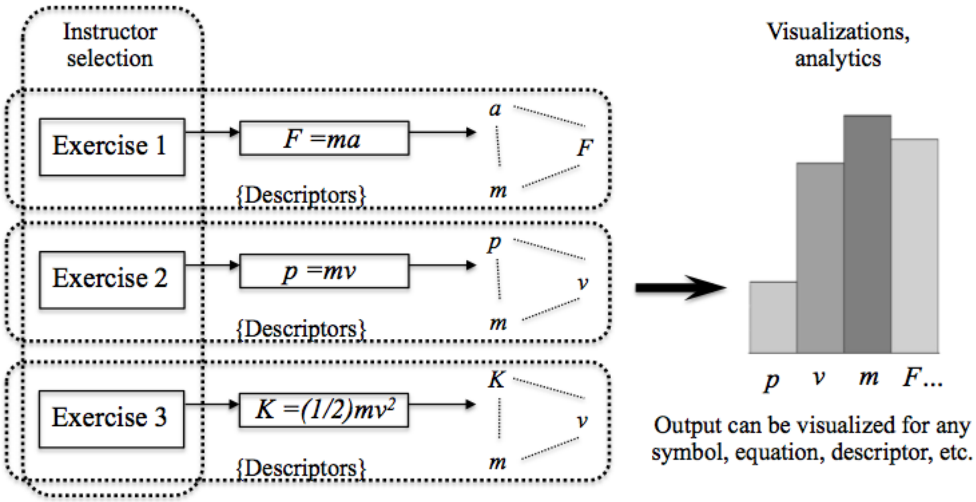

Figure 3: Descriptors used to label equations and symbols on an exercise-by-exercise basis.

phiMap usage

In phiMap, instructors may browse all available exercises by section, symbols, equations, or any available descriptor. A screenshot of phiMap's equation browser is shown on the left side of Figure 4. After selecting an equation, more information is displayed within the same pane. In this case, the equation $F = ma$ was selected. Symbols, exercises, and other equations related to F, m, and a are displayed to the right of the Equations list. Of course, instructors may wish to browse exercises by section. This is implemented through a descriptor that assigns each exercise to a "Section," as shown on the right side of Figure 4. In this case, "Simple Harmonic Motion" was selected and the chapter number, relevant equations, and corresponding exercises are listed to the right. After exercises have been selected, the entire collection is submitted for evaluation.

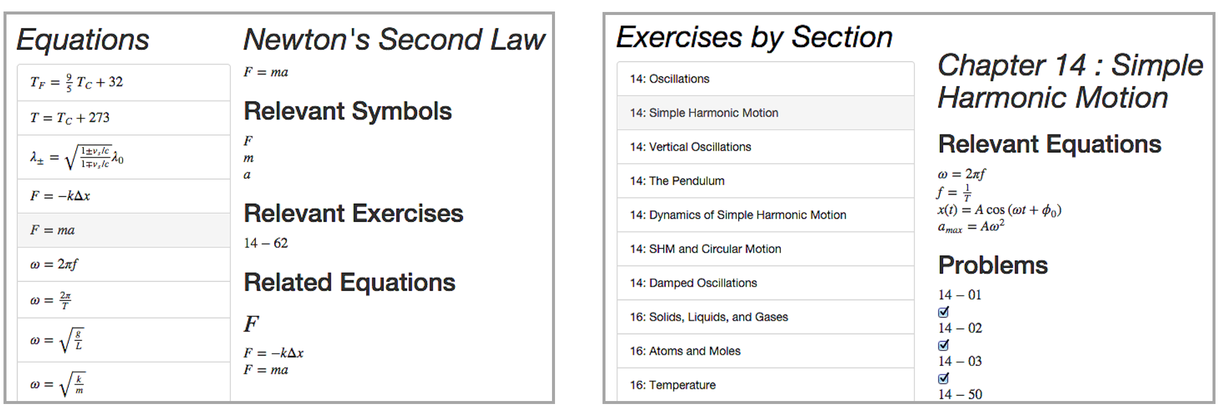

Figure 4: Screenshots of various user scenarios in phiMap.

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The data is passed to an HTML template file that generates visualizations with D3. To see this, consider a simple descriptor that labels each symbol according to its role in an exercise: either "given" if its numeric value is stated in the exercise, "find" if its value must be solved, or "hidden" if it is neither given nor explicitly sought. In Figure 5, we show two visualizations generated for an arbitrary selection of exercises. On the left, symbol frequency is displayed as a histogram, and hovering the mouse over the pie chart interactively updates the histogram to display only the symbols corresponding to that one role (given, hidden, or find). On the right, symbols are connected to their roles through a chord diagram. Since phiMap supports many-to-many relationships between symbols and descriptors, such visualizations allow the distribution of symbols among these three roles to be quickly ascertained.

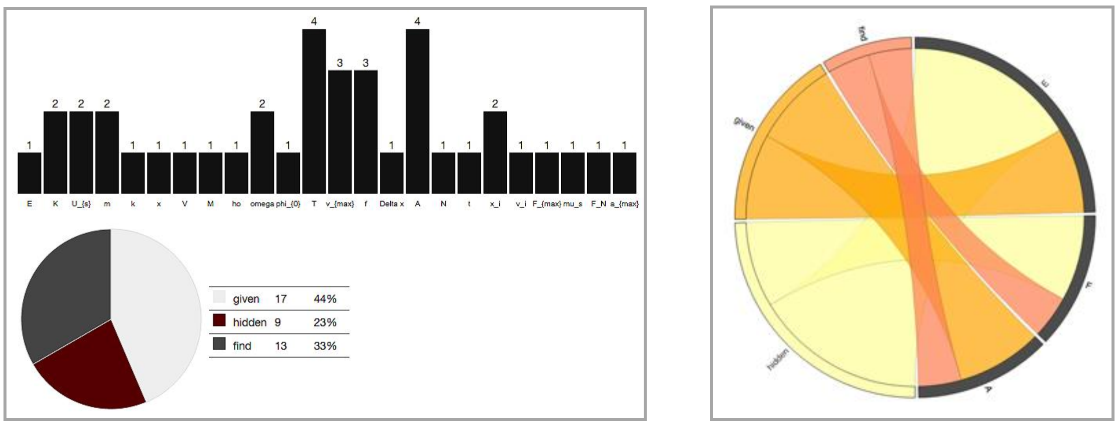

Figure 5: Sample phiMap visualizations for two selections of exercises.

Evaluating a selection of exercises

After selecting exercises with phiMap –be it for a single assignment or an entire semester– instructors receive immediate feedback on the extent to which symbols, equations, and descriptors are represented. To illustrate this, we consider the TIPP classification mentioned in the Introduction. TIPP classifies exercises by knowledge type (information and mental procedures), which are further divided into six increasingly reflective processes. Homework exercises were selected from one chapter of an introductory physics textbook[5] used at a large polytechnic state university. Exercises were classified by two students and one instructor affiliated with the phiMap project. Figure 6 displays the frequency of exercises per TIPP category for this chapter. For this sample audit, we consider only the first three cognitive processes, which in the figure correspond to retrieval (1a–b), comprehension (2a–b), and analysis (3a–e). Note that higher levels (knowledge utilization, metacognitive system, and self-system) are not represented in most introductory physics textbooks. For this particularly selection, no exercises were classified as 3c (analyzing errors) or 3e (specifying). In this case, an instructor

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could balance the overall representation by contributing exercises corresponding to these two subcategories.

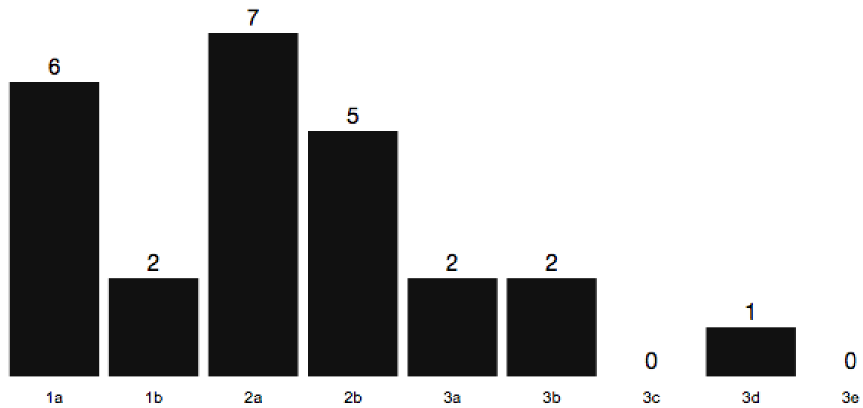

Figure 6: Distribution of TIPP categories for a selection of homework exercises from a single chapter.

Visualizations serve to convey an overall representation of the categories, as they were assigned by a group of instructors. However, descriptors are prone to interpretation, e.g., different instructors may classify one exercise into different TIPP categories. In the following section, we demonstrate how phiMap addresses this issue by calculating a level of agreement for classifications made by a community of instructors.

Inter-rater agreement

As phiMap supports the implementation of taxonomies in the form of descriptors, it is important to determine the level of agreement among assignments made by different instructors. This is relevant for validating the reliability of a taxonomy and weighting the results of an audit based on inter-rater agreement. We thus implemented Fleiss' kappa for a selection of exercises, which determines the level of rater agreement over that which would be expected by pure chance alone.

The kappa statistic is calculated as follows: let r be the number of instructors who rated N exercises into k taxonomic categories, and let n_{ij} be the number of instructors who assigned the i^{th} exercise to the j^{th} category. The fraction of assignments to category j, denoted p_j, is calculated by summing n_{ij} over all N exercises and dividing by $N \times r$. The agreement by chance P_c is determined by summing p_j^2 over all k categories. For each exercise, the extent to which instructors agree is determined in a combinatorial way as the number of pairs of instructors who agree divided by the total number of pairs possible. The final probability of agreement P_a is obtained by averaging these factors of agreement over all N exercises. Fleiss' kappa is then calculated as

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$$K = (P_a - P_c)/(1 - P_c),$$

where $P_a - P_c$ is the level of agreement above chance. The kappa statistic corresponds to an overall level of agreement among the instructors for that selection of exercises. A value of 1 indicates perfect agreement, while values of zero and lower indicate no level of agreement above chance. Kappa values between 0.2–0.4 are considered fair, while values greater than 0.60 represent substantial agreement.

There is a two-fold interest in calculating the kappa statistic, in that 1) it can identify which constructs in a taxonomy are conceptually unclear, and 2) it can help instructors determine which exercises best elicit a certain level of reflection. In both cases, it is desirable to determine which exercises have an acceptable level of agreement in order to improve the validity and reliability of an educational taxonomy. In this way, an ever-growing database of exercises tailored to modern education research can be developed in a rapid and collaborative manner.

Conclusion

We present an online Python-based platform called phiMap, which allows instructors to quickly select and view distributions of exercises along educational descriptors. Descriptors are assigned to symbols and equations on an exercise-by-exercise basis, and interactive visualizations of these distributions are generated. As descriptors are prone to subjectivity, a kappa statistic is generated for classifications of exercises made by a community of instructors.

We are presently developing an algorithm to recommend additional exercises based on specific preferences of an instructor. Such recommendations will help instructors balance their selection of homework exercises and identify which educational descriptors need to be added to the database. Finally, it has been shown that students who worked one or more additional exercises per day improved their average grade by a quarter letter, regardless of grade point average[6]. Exercises most similar to the instructor's core selection would be a natural choice for students looking for additional practice beyond their homework assignments. With phiMap, exercises that relate common principles are easy to find even across different fields of introductory physics. Such exercises could be assigned to students for background review or as advanced topics.

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Rehabilitation Robotics and Assistive Technology Experiences for Engineering Technology Students

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Abstract

The Engineering Technology Department at the College of Engineering at Cal Poly Pomona (CPP) offers degrees in two areas: Electronics/Computer Engineering, and Mechanical/Manufacturing Engineering technology. Engineering technology education is enhanced through the students' exposure to inter-disciplinary concepts that help them to generate better solutions to problems while facilitating communication with different specialists in a team. As one of the leading colleges of engineering, our mission is to link theory and practice via our learning-by-doing philosophy.
To be in alignment with this mission, students in both areas of engineering technology can take a technical elective course in robotics and applications during their senior year. In this course, they learn the basic principles of the science of manipulation along with basic control of robotic manipulators. In the laboratory portion of the course, they work in interdisciplinary teams and build a robotic manipulator with the interface to teleoperate it by using a haptic device. They apply the system for specific tasks of activities of daily living (such as lifting an object and moving it to another place etc..). In addition, those students who have an interest in biomedical applications can take independent study credits to work on extensive research/literature review of state-of-the-art technology and develop prototypes of assistive technology and rehabilitation aid devices.

Background

The engineering technology department at Cal Poly Pomona has a committed mission of educating engineers by engaging them in active learning and experimenting. Learning-by-doing is a method of education that aims at bringing students' knowledge to hands-on practice and experiments as quickly and as purposefully as possible. Over the past two decades, the method has been formally adopted by several colleges and engineering departments at ABET credited undergraduate universities. The Integrated Teaching and Learning Lab at the College of Engineering and Applied Science in the University of Colorado at Boulder is probably a pioneer in formally practicing the method and publishing scientific educational reports on the results[1-4]. Other examples of the established programs over the past two decades are the Information Engineering Technology (IET) program at the Northern New Mexico College, the University of Texas at Austin Project Centered Education (PROCEED), and reflection-in-action software engineering courses at the College of Computing, Georgia Institute of Technology[4]. The PROCEED program of UT Austin for instance was initially started in the department of

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Mechanical Engineering for undergraduate courses and has been going on for about 15 years. The program has a mission of turning students' education hands-on as quickly and as practically as possible. To reach this goal all lectures are closely accompanied by computer-aided modeling and laboratory experiment. According to the statistics provided by UT Austin's website the program currently covers 12 classes and involves many faculty members and students[3].

In all the instances of academic models for learning-by-doing that we examined, the method is either practiced as an in-class type of exercise, in the form of laboratory and computer modeling assignments, or as long-term student research projects. Depending on what form is implemented, there are always requirements and upgrades that has to be carried out at different levels for successful results, including:

1) Modifying classroom content and presentations to provoke students' participation
2) Restructuring homework assignments and course evaluation system
4) Modernizing classrooms and laboratory equipment for facilitating experimental observation and education for students, and providing access to computer-aided design and engineering programming tools.
3) Defining modern collaborative research projects for students
5) Establishing strong partnership with industry
6) Designing interdisciplinary courses and research projects that require students to self-educate on broader scales of topics and study areas.

At the department of Engineering Technology at CPP, these elements are emphasized and practiced regularly at teaching and in-class levels. As the department is leaning towards establishing a strong research program in addition to existing teaching infrastructure, efforts have been dedicated to develop more active undergraduate research projects and elevate learning-by-doing capability of the department at the research level. To that aim, it is crucial to focus on multidisciplinary areas of research that also have the potential of partnership with strong industrial sides. The field of biomedical robotics is in a way unique in satisfying both of these two criteria. Robotics and biomedical engineering are both extremely multidisciplinary and vast areas with practical essence for different levels of hands-on experiments. Students involved in rehabilitation robotics research have a chance to acquire a background in multiple areas such as engineering of mechanical moving and dynamic parts, control systems, electrical sensory motor systems, neurological systems and some levels of medical science. Additionally, due to large amount of global research activity and public interest in biomedical robotics, there are numerous opportunities for industrial partnership. In fact, this field is so suited for undergraduate research education that the Engineering Department at CPP has exclusively established a Robotics Education through Active Learning (REAL) program. According to [5], "REAL is designed to inspire students and prepare teachers. REAL is the culmination of an extensive, six -year collaboration among engineering faculty, undergraduates, and K-12 teachers in robotics-based education to engage and inspire learners".

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Rehabilitation robotics is the engineering of applying robotics to retrieve muscle and nervous system functionality in people who has disabilities due to neurological disorders. These robotic devices can act both as supportive tools to facilitate regular actions of the disabled body parts, or help retreat motions in clinical or real-life experiments. Originally it dates back to 1990s when major break-through accomplishments occurred in robotic and biomedical technology[6] and it has been a very active clinical and commercial research field since then. Rehab robots can be primarily categorized based on the region of body that they serve to improve motor movement. The majority of rehab robots are designed to assist patients or disabled people recover movements in arm, spines and legs. Therefore, the most common types of rehabilitation robotic devices are: aiding limb or hand movement exoskeletons, enhanced rehabilitative (e.g. antigravity) treadmills, robotic arms, finger rehabilitative devices and motorized neck braces.

Rehab robots can be either passive or active and can also be classified based on the type of user interaction and degrees of freedom in controlling patients movements (e.g. the number of contact points)[7]. Conventional rehabilitative robots which were mostly adopted from industrial robots were mostly robotic manipulanda with one point of contact between the robot and patients body, whereas more modern robotic orthosis consist of continuous or multiple point contacts with the body[7].

At present, the market of rehabilitation robotics engineering is extremely active and extends to commercial products and clinical experiments. A few notable examples of commercial devices are:

Bionic Legs:

1) Tibion Bionic leg of Tibion Corp. which is designed mostly for stroke patients whose leg functionality are affected by the condition, and provides the opportunity to stand safely, walk and climb[8],

2) Ekso Bionic Leg of Ekso Bionics which is the producer of exoskeletons for survivors of stroke or spinal cord injury or other forms of extremely weakness that facilities walking. Ekso has strong research ties with UC Berkeley and has been supported by the US Department of Defense.

3) AlterG which is a producer of both bionic leg and anti-gravity treadmills

4) Rewalk which is a producer of bionic walking assistance systems for standing upright, walk and climb stairs.

Treadmills:

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1) Lokomat treadmill by Hocoma which according to the company's website is a "driven gait orthosis that automates locomotion therapy on a treadmill and improves the efficiency of treadmill training". Hocoma, a Zurich based company also produces other products such as Erigo (combined leg robotic assistant and back stabilizer system), and Arimo (robotic arm and hand rehabilitative system)

2) AlterG anti-gravity treadmill

Robotic Arms and Finger Braces:

1) Myomo robotic arm brace (MyoPro) which is designed to assist patients in need of arm rehabilitation or robotic assistance due to stroke, neurological damages such as MS, Traumatic Brain Injury, Amyotrophic Lateral Sclerosis, Spinal Cord Injury or Brachial Plexus Injury.

2) Amadeo of Tyromotion which is a finger and hand rehabilitation system.

3) Bi-Manu Track of Reha Stim (a Germany-based company) which is one of the very early clinical devices for reanimating arm movements by initiating both passive and active mode moves and allowing the brain to mirror the healthy side moves for rehabilitation of the unhealthy side.

4) HapticMaster of Moog Inc. a company involved in design and manufacturing of motion control technology for military (space, submarine, etc.), energy, industry and medical customers, and is also the producer of Wristalyzer (a wrist perturbator device) and Dental Trainer (simulator) products.

There are also several notable example of clinical and academic rehab robotic systems. These systems are often more advanced in terms of the underlying pattern-based training and software than the stand-alone commercial products. A few of the most notable systems are:

1) MIT Manus (a.k.a InMotion) which is an arm rehab manipulanda robotic system developed at MIT and is based on an interactive smart training software for best treating patients with neurological disorders[9].

2) Mirror Image Movement Enabler (MIME) developed at Stanford University with 2 degrees of freedom which is also an arm rehab system[10].

3) Therapy-Wilmington Robotic Exoskeleton (T-WREX) developed at UCI which is a passive arm exoskeleton orthosis[11].

4) Reharob of the Budapest University of Technology.

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5) The ARMin system developed at ETH University which is an arm therapy robotic system[12].

Sample Student Projects

1. Mechanical Prototype for Bimanual Rehabilitation for Stroke Patients

An interdisciplinary team of mechanical and electronics and computer engineering technology students investigated various robotic devices currently employed in upper limb rehabilitation for post-stroke patients. After extensive literature review, they focused on the work done by researchers at the University of South Florida[13] on bimanual rehabilitation devices and developed a basic prototype. The idea of a bimanual rehabilitation device is to allow an individual to self-rehabilitate by guiding his paretic arm with his healthy arm using an external physical coupling.

With regards to actual rehabilitation exercises, the device must be able to allow three main types of bi-manual rehabilitation exercises; joint space symmetry, point mirror symmetry and visual symmetry. All three can be accomplished through a combination of joints and linkages available through the device. The device consists of one revolute joint and three prismatic joints.

The prismatic joints allow for motion in the x and y planes, which facilitates visual symmetry and joint space symmetry exercises. The revolute joint is rendered immobile for these motions through the use of a pin. Two of the prismatic joints are used to connect the stroke affected arm with the healthy arm through a pulley system. This system allows each arm to either mirror or oppose the actions of the other arm, depending on how the lines routed through the pulleys. For example, the arms can be made to close or increase distance with one another such as a clapping motion, or to move together in the same direction where one arm mirrors the motion of the other. The third prismatic joint allows the entire assembly to travel in the y axis, allowing for movements either away from or toward the patient. For the exercise requiring point mirror symmetry the revolute joint is freed by removal of the pin and the y axis degree of freedom is removed by use of a friction lock. The two prismatic joints allowing for travel in the x axis are linked to allow for a mirrored motion where the arms will either come together or travel apart.

In constructing the device, simple materials such as plywood and aluminum were used to keep the overall costs efficient. The rails used for movement in the y axis are industry standard extruded Aluminum t-slots available from a number of suppliers. Arms for the device are sized to be standard Aluminum square stock to minimize machining time. The base for the device is ½ inch plywood for ease of transport and assembly. Figure 1 shows the SolidWork model designed by the students, and Figure 2 shows a picture of the mechanical prototype.

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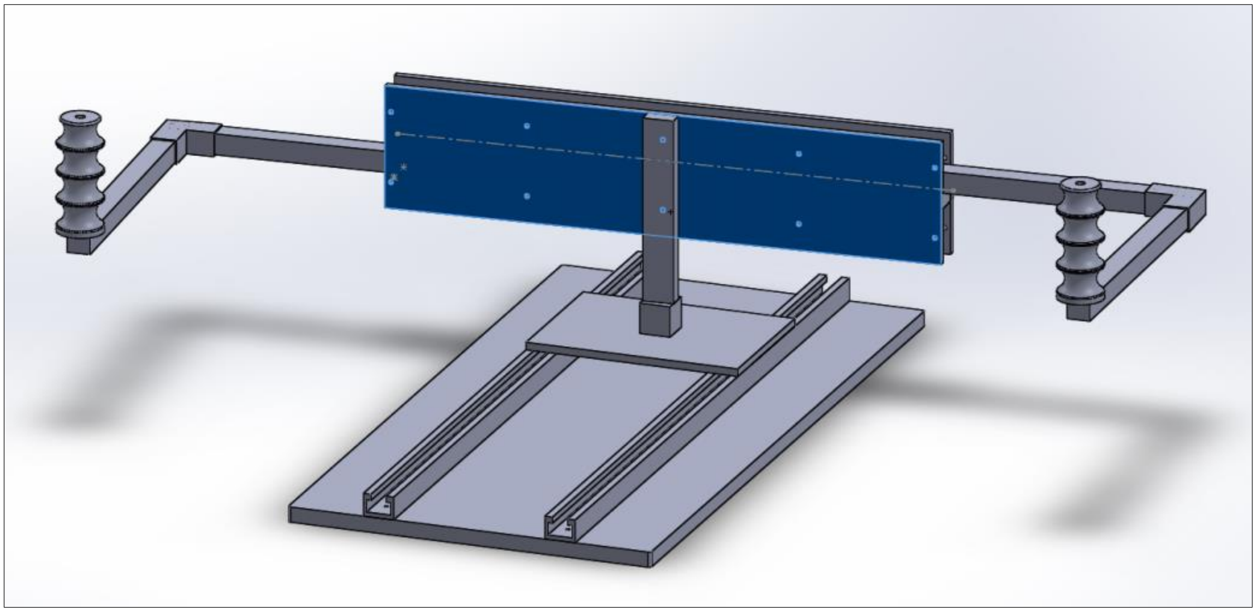

Figure 1. SoliWorks Model for the Bimanual Rehabilitation Robotic Device

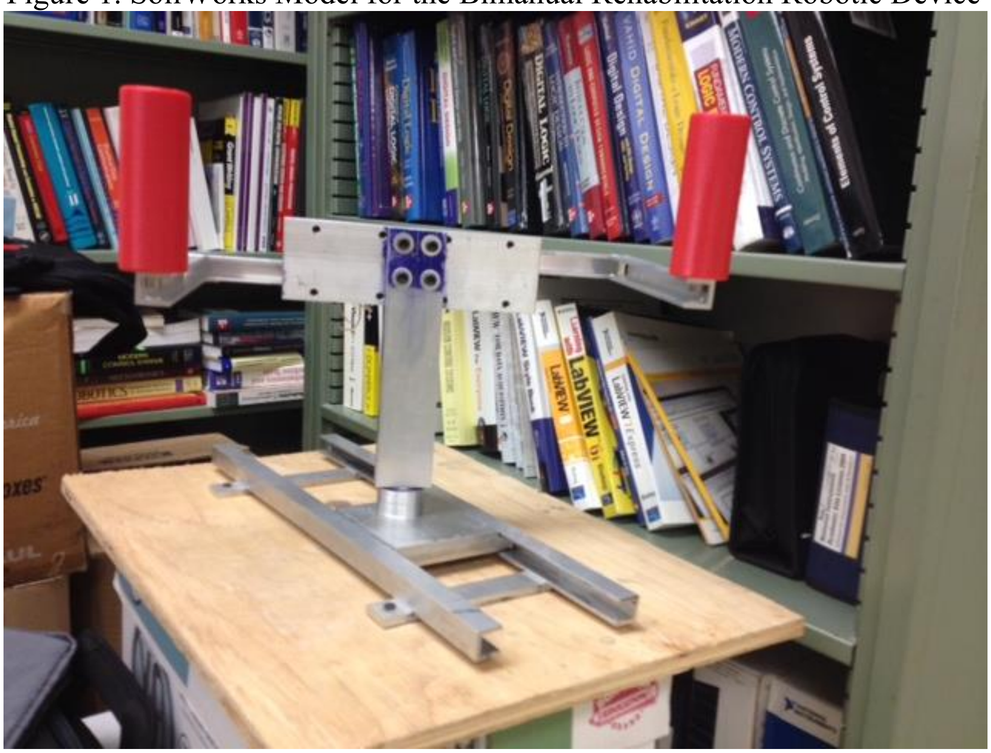

Figure 2. Mechanical Prototype for the Bimanual Rehabilitation Robotic Device.

2. Motorized Neck Brace for Rehabilitation Exercises

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Another team of students developed a motorized neck brace for people in need of neck rehabilitation exercises, or people who have lost motion and control of their neck. The goal was to develop a brace that not only assists the user with neck rehabilitation but also improves peripheral safety. The brace use is considered a dynamic assistive step before it is fully removed, and has even long term applications for patients with neck paralysis.

The prototype developed provides support through a limited range of motions which allow for quicker neck rehabilitation. It is not intended to solely limit motion like a conventional neck brace does by applying resistive loads, as that could be very uncomfortable for the user. For patients in need of neck rehabilitation, the motorized neck brace allows for an adjustable range of motion which will allow for faster healing times. Increased peripherals reduce eye fatigue and increases safety by adding more peripheral viewing and less wear on the user. In order to adjust the appropriate electric motor weight specifications, a standard weight of an adult head and length of the spinal column were taken into account. Figure 3 shows the working prototype.

Figure 3. Motorized Neck Brace Prototype

3. Derailleur Gear Wheelchair Proposal

Another team of students conducted literature search and presented a proposal that could give future students the opportunity to develop the working prototype. This proposal presents the implementation of a derailleur gear system capable of transitioning an individual between various speeds and easing overall mobility of a wheelchair. The finished product will consist of modifying an existing wheelchair to be compatible with a gear system that the user will be capable of operating. This added feature will be directly mounted to the frame of the chair and attached by two hand operated levers for ease of access, providing stability and extra control to the user at an affordable cost compared to electric powered alternatives. The device will be

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installed so that the user can move with less energy expended and easily propel themselves up steep inclines while experiencing less muscle strain. Figure 4 shows the proposed idea

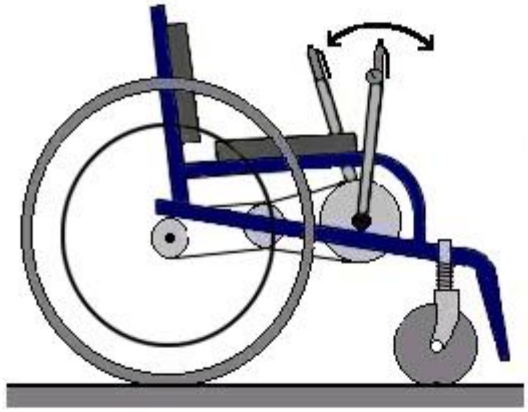

Figure 4. Proposed Idea for a Derailleur Wheelchair

4. Telerobotic Haptic System

Engineering technology students take a technical elective course in robotics during their senior year. In this class, they design and build a telerobotic (master-slave) system to execute a simple activity of daily living. They use a Novint Falcon haptic device on the master side and build a manipulator for the slave side of the system. They design and build the interface in LabVIEW and design and build the electronics to control the slave manipulator. Some students have adapted off-the-shelf robotic kits for the slave manipulator. Figure 5 shows two of the systems.

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Figure 5. Telerobotic Haptic Systems

Conclusion

Engineering technology students from both areas have shown great appreciation of the opportunity given to work in interdisciplinary teams applying their knowledge to biomedical related problems. The field of rehabilitative robotics is an excellent opportunity for students to perform hands-on research on various engineering topics. Therefore the Engineering Technology department at Cal Poly Pomona has a particularly dedicated program in this area. These projects have provided engineering technology students an experience in line with the learn-by-doing philosophy at Cal Poly Pomona. In this paper, we reported several student projects in designing robotic systems for patients with disabilities due to stroke or other neurological disorders. These projects include a Mechanical Prototype for Bimanual Rehabilitation for Stroke Patients, a prototype for Motorized Neck Brace for Rehabilitation Exercises, a design proposal for a Derailleur Gear Wheelchair Proposal, and a LabVIEW interface for designing Telerobotic Haptic System.

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Attentional demand, encoding, and affective payoff of context-rich physics problems

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Abstract

Problems from introductory physics courses are often presented in minimal form. Such problems reinforce formulaic thinking, meaning that students focus on equation hunting instead of physics principles. Alternative problem types, such as context-rich and qualitative problems, have been considered as means of addressing this issue. However, their usage is far from being standardized, and evidence still lacks regarding the type of thinking they exert. This study explores the facets of solving context-rich and qualitative introductory physics problems among 25 students and 6 instructors. Analyses of fixation times and recognition performances revealed that while students spent more time fixating on physics quantities than instructors, their memory trace of the problems was fairly comparable. Likert scales revealed that students found both types of problems to be less confusing and more engaging than did instructors.

Introduction

The major challenge of science, technology, engineering, and math (STEM) education is the development of pedagogical methods that foster deep learning, expert-like skills, and construction of conceptual knowledge (for an overview, see Hoskinson et al.[1]). Problem solving, whereby one applies abstract principles in an expert-like fashion in order to achieve a goal, plays a central role in this endeavor.

In physics, such abstract principles are commonly embodied through equations and instantiated through word problems. Problems often refer to idealized objects or events (e.g., a block sliding on an inclined lane). Yet, rather than eliciting abstract thinking, such problems reinforce rote association with formulas and restrict transfer toward "real-life" situations. Many scholars deem idealized problems responsible for students developing a formulaic approach toward problem solving (i.e., "plug and chug"), and ultimately leaving introductory courses with poor conceptual knowledge in physics[2].

Promises and shortcomings of context-rich problem solving

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Strategies have been proposed to address this issue, such as subjecting students to problems that are context-rich[3] and/or qualitative[4]. Key attributes of such problems are given in Table 1.

Qualitative problems	**Context-rich problems**
- formulated in idealized terms - require predictions and explanations in place of mere calculations	- provide a motivation for calculating specific quantities about real objects or events - do not explicitly state what is wanted, so the solver must determine appropriate wanted quantity - often provide excessive information - do not make all information required to solve the problem explicit - leave reasonable assumptions to the solver

Table 1: Typical attributes of conceptual and context-rich problems.

Problems with the above attributes make it harder to map stated quantities with matching formulae. They require, prior to solving, that students conceptualize the problem at the level of its physics principles[5]. Note, though, compared to qualitative ones context-rich problems are under-represented in introductory textbooks and may pose several issues. First, their benefits are far from evident. Rand found that context-rich problems did not have any significant effect on student exam scores[6]. More generally, there are no standardized methodologies in the education community for comparing problem types in terms of their learning impact. In other words, the reasons why qualitative, context-rich, and other problem types may be advantageous have yet to be clarified. Second, since context-rich problems are rather challenging, it is believed that students are less likely to solve them on their own. In fact, others recommend that context-rich problems be administered under prescriptive training and cooperative settings (i.e., worked in small groups, see Heller and Hollabaugh[3]). Yet, asking instructors to teach problem solving in groups is not an easy task. Moreover, Yerushalmi et al. identified that faculty worry that problems with challenging features (context-rich, multistep, etc.) will conflict with clarity of presentation and cause stress for students[5].

Background research and open questions

A better understanding of the impact that context-rich vs. qualitative problems exert on learners may help to resolve the above issues. Cognitive research on expert-novice differences offers a framework for such a study. The literature has established that, contrary to experts, novices lack abstract representations, called schemata, thanks to which automatically attending thematically

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relevant information and underlying principles. Also, students' understanding of an equation is often intertwined with surface details of the problem, at the expense of the underlying principle[7]. When confronted with word problems, novices would construct mental representations that reflect mechanism of textual comprehension more than physics-related thinking. For these reasons, novices may have harder time stripping away excessive information in context-rich problems (cf. Table 1).

The latter issue likely manifests itself in the way context-rich problems are visually attended to. Prior studies have shown that experts require shorter fixations, as well as fewer fixations and saccades, to process different zones of a problem (e.g., problem statement vs. graph vs. multiple choice widget[8]). In addition, novices may fixate on physics quantities differently based on their status in the problem. Notably, novices have been documented to rely on backward inference, namely matching a formula that contains the problem goal[9]. In comparison, experts would apply an equation to the information given in the statement of the problem and see if that strategy realizes the goal. Along these lines, one can expect students to fixate on physics quantities differently than would experts.

The trace of a problem formed in one's memory reflects the attention allocation and strategies deployed during its solving. Verbal protocol analyses have revealed novices' representation of problems to be detailed and less thematic than that of field experts[7]. According to recognition tests, novices remember more features of a problem diagram, even those that are non-meaningful and less thematically relevant[10]. This raises the concern that problems excessive in content may lead students to encode more irrelevant information, thereby hindering abstract thinking even more than traditional problems. Lastly, problems that students find less straightforward/clear may be more of an asset than a drawback. Research into affective states suggests that, despite its negative emotional valence, confusion can involve a deeper learning than engagement alone[11]. In this sense, problems that elicit both engagement and confusion would seem desirable.

Study objectives

The present paper extends aforementioned research on problem solving in two directions: (1) characterize the attentional, processing, and affective effects exerted on learners by context-rich vs. qualitative problems, and (2) determine which problem features underlie such effects.

The first direction was addressed by comparing gaze behaviors, recognition performances, and Likert scale ratings between novices and experts. Gaze behavior is a good indicator of visual attention: not only does gaze location reflect information that is attended to, but longer fixations suggest deeper processing[8]. The latter, though, does not come down to merely allocation of visual attention (viz. Midas touch effect). Likewise, memory paradigms (or "tests") that

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retrospectively characterize processing complement the analysis of gaze behavior. Such is the case with a Remember/Know recognition paradigm (R/K for short) in which participants are asked to identify the nature of their recognition of a previously studied item. To summarize the utility of this paradigm, participants provide two exclusive responses: "Remember" responses when items whose source or context of encoding are recollected, and "Know" responses otherwise. Both responses serve to compute so-called recollection and familiarity scores (Eqs. 1-4). Typically, elaborative processing increases recollection yet not familiarity. Hence, should context-rich problems require more elaboration (e.g., construction of semantic or conceptual relations among problem tokens) than qualitative ones, a selective increase of recollection scores should be observed[12]. Finally, Likert scales for confidence in answer, confusion, and engagement of problem were formulated to address the affective impact of problem solving[5,11].

The second direction was addressed by analyzing gaze behavior at the level of features characteristic to physics problem solving. Concretely, we manually coded sentence tokens for each problem according to the scheme illustrated in Fig. 1.

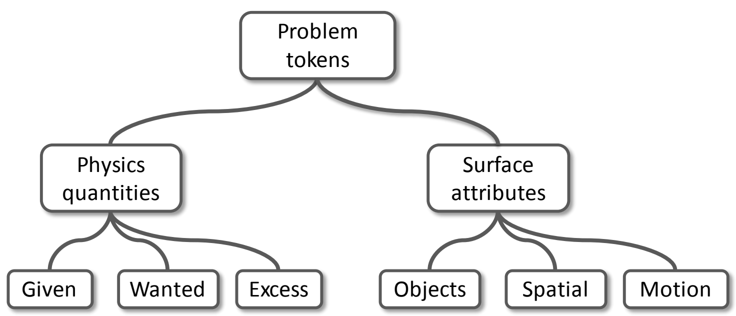

Figure 1: Problem feature coding scheme.

Methods

Participants

This study presents data collected among 25 students and 6 instructors recruited at a large polytechnic state university. The students were enrolled in a one-semester calculus-based physics course, and had had about two weeks' worth of lectures covering simple harmonic motion. Most were sophomores or juniors who had already taken a course in mechanics. Students, who are considered novices, were given extra-credit for their participation. Instructors included professors and full-time lecturers. These field experts participated in the study voluntarily.

Materials and apparatus

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Five word problems[1] on kinematics of simple harmonic motion were designed. One problem was very simple and served as filler, two were qualitative, and two were context-rich. As shown in Fig. 2, each context-rich problem was designed to be analogous to a qualitative one by drawing upon the same underlying physics principle.

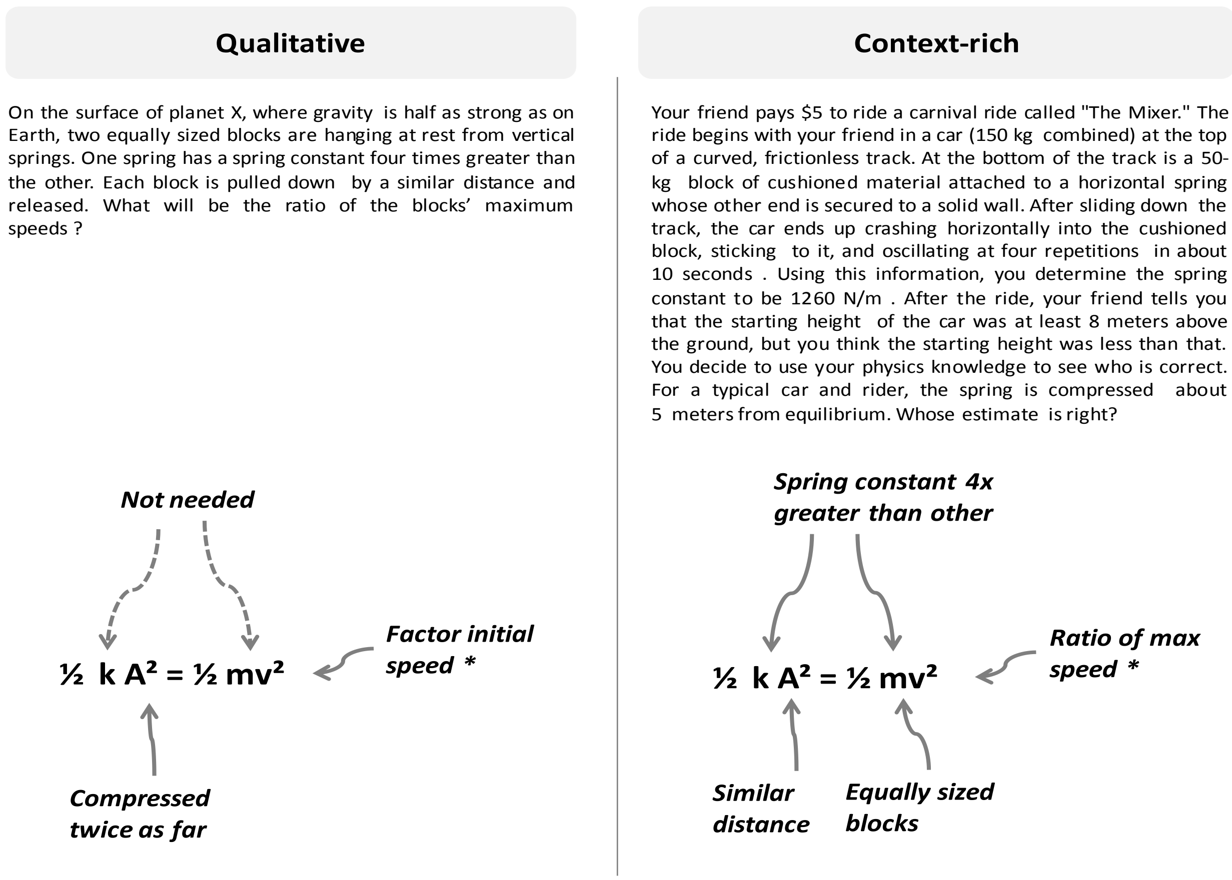

Figure 2: Qualitative and context-rich examples. "" indicates the wanted quantity for each problem.*

Qualitative problems were modeled after standard end-of-chapter exercises from Knight[13]. Context-rich problems were designed after Heller and Hollabaugh's recommendations[3]. They were realistic stories that used the personal pronoun "you," included plausible motivation, and allowed two solving approaches (e.g., dynamics or conservation of energy). Additionally, they

[1] The problems contained only text, no diagrams or illustrations.

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were made more challenging through excess information, unknowns that cancel, and wanted variables that are not explicitly stated (e.g., "is your friend's estimate correct?").

Likert scales corresponding to confidence, engagement, and confusion are given Table 2.

Likert	Students	Instructors
Confidence	How confident were you with your answer?	How confident were you with your answer?
Engagement	Was that problem more or less engaging than a typical homework?	Was that problem more or less engaging than a typical homework problem you would assign to your students? (1 = much less, 5 = much more)
Confusion	Was that problem confusing in any way?	Do you think this problem would be confusing to your students in any way?

Table 2: 5-point Likert scales.

Open questions were formulated that required participants to recall their physics background and interests. These questions were meant to de-buffer participants' short-term memory before the R/K test. This latter test was designed by selecting equal numbers of words from the two problem types and generating an equal number of distracters using hypernym and hyponym methods from WordNet[14]. Targets and distracters were displayed in a web browser in two pseudo-random orders above the button choices "No", "R", and "K" – the latter two which stood for "I remember" and "I know".

The study required two workstations: one for eye tracking, Likert rating, and question answering; the other one for the R/K test. Gaze behavior was recorded during problem solving at a sampling rate of 250 Hz with an SMI RED 250 remote eye-tracking system, which is a fiducial- and contact-free setup integrated into the bottom of a 22-inch flat-panel monitor. The problems were displayed on this monitor with a resolution of 1250x1024. Their layout was such that the inter-word distance was greater than 0.5° degrees.

Procedure

Each participant took part in one session lasting approximately 30 minutes. Upon signing an informed consent form, the participant was seated at the eye-tracking workstation, about 65 cm in front of the monitor. S/he was handed an instruction sheet regarding use of a calculator, rounding of answers, role of the test moderator, and importance of staying focused on their task. The moderator calibrated the SMI to each participant using a brief nine-point calibration and validation procedure. Unless the validation was accurate to a visual angle of less than 0.6°, the procedure would be repeated up to four times, and best calibration parameters were used.

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To get accustomed to the study, each participant began by solving a filler problem, under moderator guidance, which was not counted toward the data. After the filler, participants were left on their own to solve 4 problems, *i.e.* work the solutions and report the answers on separate pages of a handout[2]. Each page was to be turned after completion and the participant was asked to not look back at previous responses or work. After each problem, the participant was prompted onscreen to rate confidence, confusion, and engagement. Once the last problem was solved and rated, the studied resumed with questions pertaining to their physics background and interests. The participant was then seated at the second workstation and performed the Remember/Know test after reading an instruction sheet.

No performance criterion was enforced through the study. In the event that a participant took more than 30 minutes, s/he was asked to skip the remaining problems. For any skipped problem, the corresponding Likert scales and R/K items were excluded from later analysis. Note that participants whose calibration accuracy exceeded 0.6° were not counted toward the analyses. Since the case number (viz. problem solved, Likert scales rated, R/K items studied) could differ from one participant to another, impacts of problem type, expertise, and other descriptors were evaluated with a Mixed-Effect Model in SPSS.

Results

Attentional demand

The gaze metric for attentional demand was the average fixation time (ms). Concretely, it corresponded to gaze stabilizations greater than 200ms on any problem feature listed last row of Fig. 1. The best model fit was a factorial design with expertise (students vs. instructors), problem type (qualitative vs. context-rich), and problem features (excess vs. given vs. motion vs. object vs. spatial vs. wanted) as predictors, plus the intercept for participant and problem as random variables, with a variant component covariance structure. This model produced a significant main effect of problem feature ($p < .001$), which was qualified by an interaction with expertise ($p < .05$, see decomposition in Fig. 3).

[2] Pre-tests had been conducted that ensured that participants looking down their calculator and handout did not disturb the recording of their problem- and thus onscreen- gaze behavior.

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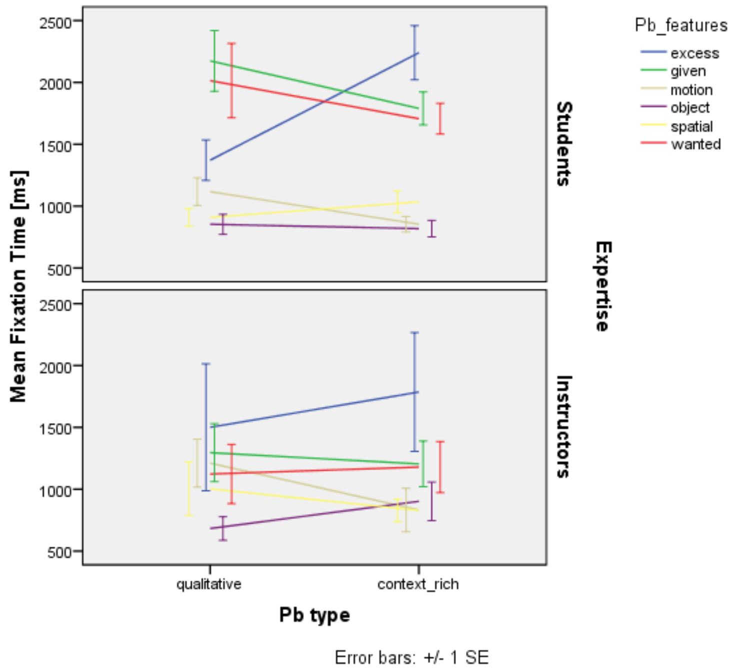

Figure 3: fixation times as a function of problem type, feature and expertise.

Analysis of students only indicated a main effect of problem feature ($p < .001$), which interacted with problem type ($p < .01$). Bonferroni post hoc analyses indicated that students fixated on excess (M = 1714, SE = 506), given (M = 1977, SE = 500), and wanted features (M = 1858, SE = 500.61) significantly longer than on motion (M = 977, SE = 500), spatial (M = 1030, SE = 507), and object features (M = 818, SE = 501), with *p* levels all less than 0.005. The interaction was such that students fixated on excess features significantly longer during context-rich problems (+1023 ms, $p < .005$) than qualitative ones.

Analysis of instructors only showed a main effect of problem feature ($p < .05$). According to Bonferroni post hoc analyses, all features were comparably fixated on except for objects (M = 779), which instructors fixated on for significantly shorter times than excess features (M= 1561; $p < .05$). The absence of interaction for this effect with the problem type seems coherent with the notion of field experts being less sensitive to surface manipulations than novices.

Encoding in memory

Remember, know, recollection, and familiarity scores were calculated along Equations 1-4, respectively (Yonelinas and Jabocy, 2013):

$$\text{Remember Scores} = p(\text{Remember}|\text{old}) - p(\text{Remember}|\text{distracter}) \qquad (1)$$

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$$\text{Know Scores} = p(\text{Know}|\text{old}) - p(\text{Know}|\text{distracter}) \tag{2}$$

$$\text{Recollection} = \text{Remember scores} \tag{3}$$

$$\text{Familiarity} = \text{Know scores} / (1 - \text{Remember scores}) \tag{4}$$

The best model fit was a factorial design with expertise (students vs. instructors), problem type (qualitative vs. context-rich), and recognition (recollection vs. familiarity) as predictors, plus the intercept for participant and problem as random variables, with a variant component covariance structure. This model produced a significant main effect of recognition level ($p < .001$), with significantly greater scores in recollection (M = 11.3, SE = 2.9) than in familiarity (M = 2.8, SE = 2.9). Predictor estimates indicated a significant increase of scores for items from context-rich problems (+7.44, $p < .05$) compared to qualitative ones, an increase in recollection (+7.17, $p < .001$) as opposed to familiarity, and a marginal increase in the recollection of items from context-rich problems (+3.7, $p = .08$) as opposed to their familiarity. In sum, context-rich problems yielded an elaboration effect over qualitative ones, among both students and instructors.

Affective impact

Likert scales were averaged per problem type. The best model fit was a factorial design with expertise (students vs. instructors), problem type (qualitative vs. context-rich), and scale (confidence vs. engagement vs. confusion) as predictors, plus the intercept for participant, and scale as a random variable with a diagonal covariance structure. This model produced a significant main effect of expertise ($p < .001$), scale ($p < .001$), and their interaction ($p < .01$). The interaction of problem type and scale was marginally significant ($p = .051$).

Separate analyses of each scale revealed a main effect of expertise on confidence ratings ($p < .001$). Predictor estimates indicated higher ratings from instructors (+.92, $p <.05$) than students, and for qualitative problems (+.72, $p < .005$) compared to context-rich ones. There was a significant effect of expertise on confusion ratings as well ($p < .05$). Predictor estimates indicated higher ratings from instructors (+.99, $p <.05$) compared to students, and for context-rich (+.74, $p < .005$) compared to qualitative problems. We found a significant effect of problem type on engagement ratings ($p < .05$), with predictor estimates indicating higher ratings for context-rich (+.44, $p < .01$) compared to qualitative problems. This latter outcome is particularly interesting, as it suggests context-rich problems, while more challenging, may be still more interesting to students.

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Discussion and perspective

In this study, we investigate how students deal with qualitative and context-rich problems. At the attentional level, we found that students dedicated more attention to excess, wanted, and given features than did instructors. In particular, fixation times increased for excess features of context-rich problems. We conceptualize this outcome with respect to the problem feature taxonomy of Fig. 1. Excess features fell into the same grouping as surface attributes in the case of qualitative problems, namely students recognized that they did not constitute core statements. Yet excess features moved closer toward the grouping of relevant physics quantities in the case of context-rich problems, meaning students took more time to determine if they should be ruled in or out of the core problem statement. Excess features seem consistent with the notion that context-rich problems should make it harder for students to resort to mere formula matching. Neither motion, spatial, nor object features, which were more numerous and more convoluted in context-rich problems than in qualitative ones, seemed to support such an endeavor. At this stage, our study suggests that excess features would be more relevant than the other features we tested in rendering a problem less formulaic.

At the representational level, we found context-rich problem to require greater elaboration than did qualitative ones, regardless of participants' level of expertise. At the affective level, students rated the problems as less confusing than did instructors and found them more engaging than typical homework problems (i.e., idealized). In this sense, the problem types tested in this study are good candidates for tapping the affective states relevant to deep learning[11]. Context-rich problems seemed to satisfy this requirement in particular.

This study examined the potential strengths and limits of elaborate problem types in an experimental setting. Our results suggest that instructors looking to address formulaic thinking may simply add excessive physics quantities instead of excessive surface attributes (i.e., story details). Context-rich problems required more elaboration according to an R/K test, and made students feel more engaged according to a Likert scale. Future research is still needed to complement the present study and translate these findings into concrete recommendations for STEM curricula.

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RFI DISCUSSION FORUM

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Abstract

The construction process involves many different professionals that are in charge of making important project decisions in their own area of expertise. In many projects there will be unforeseen circumstances that arise that will require the contractor to request additional information from the professional qualified to devise a practical solution to the problem. This process of sending a request for information is commonly known as the Request for Information (RFI) process. The RFI process can occur multiple times on any given project and for many different reasons. These requests have the potential to hinder construction and, therefore, need to be resolved promptly in order to minimize the impact they could have on the flow of production. One option of expediting the RFI process time would be to create a submission process that incorporates the use of instant technology through the internet, such as the implementation of an RFI discussion forum. Having this avenue of immediate communication could have many benefits including increased project transparency, increased accountability amongst project professionals, and reduced occurrences of non-value adding activities.

Introduction

The response time of an RFI could have a huge impact on a project as inflated cycle times can affect the overall project schedule and the sequencing of downstream tasks[6]. Further complications can arise if there are additional procedures that must be followed during the RFI process or contracts that dictate the communication sequence between the professionals. Furthermore, many of the activities that are required to process an RFI are underestimated in their allotment of time, are severely unreliable, lack transparency, and include activities that do not add value to the project's main objective[5]. The goal is to seek out areas of improvement in the RFI process and to offer possible strategies to reducing the cycle time.

The RFI process must first be defined and analysed in order to find areas where improvements could be pursued. One method of analysis is to apply the principles of lean construction, presented by Lauri Koskela, such as building continuous improvement into the process, reducing the amount of steps, parts, and linkages, and increasing process transparency[4]. Once the lean construction principles are established, a plan can be devised in order to apply these principles to the RFI process in an effort to increase the process efficiency.

One method of applying the lean construction principles to the RFI process is to create a discussion forum format for RFI submittals. Having the ability to submit a project's RFIs in a discussion forum could potentially have many benefits to a project such as a reduced number of steps in the process, an increase in project transparency, and an increase in communication amongst the professionals. This is valuable to the contractor because there should be a higher level of confidence that the RFI will reach the appropriate professional within the shortest amount of time, and the opportunity for increased communication amongst the consultants should yield to a reduced number of inconsistencies and ambiguities in the RFI responses.

In order to test the theory of the RFI discussion forum, a simulation was created. There are two scenarios to this simulation. The first scenario represents an RFI submitted on a project that has a contractual communication sequence that must be followed through the standard, web-based avenue of RFI submittals. The second scenario represents an RFI submitted in a discussion forum, which allows the information to be instantly available to all of the professionals involved and provides instant notification when a response is submitted. The results of the simulation confirm that the use of the RFI discussion forum supports the intended lean construction principles and increases the overall efficiency of the RFI process. Furthermore, these simulations can be used as tools in a classroom or office setting in order to emphasize the value of transparency and communication within the construction industry.

The RFI Discussion Forum

The RFI process was created as a communication tool in order to clarify or resolve design issues[1]. The basic function of the RFI will remain unchanged regardless of the methods used to request the necessary information. An RFI will generally be submitted by the general contractor and should contain information such as references to drawing numbers or specification paragraphs, identification of the information being requested, and the impact that this RFI will have on the project schedule. The response will be from the architect or the consultant that is responsible for that part of the design[7]. An RFI can be submitted either early on in the bidding phase or at any point during construction. If an RFI is submitted after the commencement of construction it could bring about more challenges in developing an appropriate solution. For example, any areas that have already been constructed will preferably need to be protected in place rather than altered, and any downstream tasks could have their schedules hindered. Due to the time sensitive nature of the RFI, finding and solving any issues on a project early on can help shield the other tradesmen from uncertainties and prevent costly delays[2]. The image below is a depiction of the typical RFI review process.

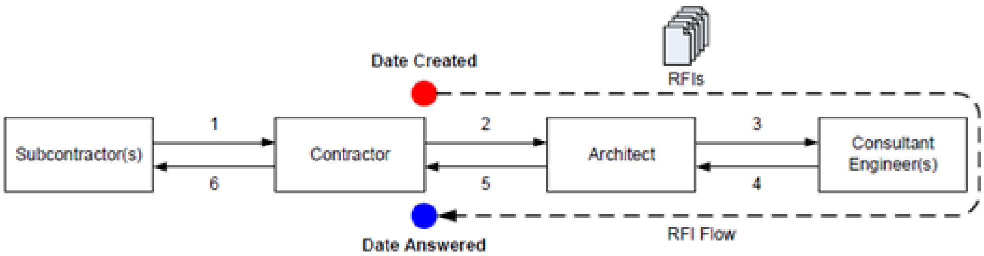

Figure 1.a: Typical RFI Review Process Flow[7]

The RFI discussion forum is a tool that can be used to help solve many of the issues that arise during the construction process. It could simplify the communication between the project decision makers and it can be applied to any project regardless of size or contract type. The discussion forum is intended to be implemented by the stakeholders early on in the development phase and should be preset with the list of professionals that will have access to the forum and who will want to receive the RFI alerts and notifications. The discussion forum

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will be accessible from any internet capable device, the RFI template will have been pre-selected by the stakeholders, and the contact information for all the pertinent professionals will be pre-loaded and automatically grouped; therefore, when the contractor is ready to submit an RFI, he will simply log in to the forum, enter information being requested, and submit.

Once an RFI is submitted, the computer program will instantly send notifications, which can be received by any computer or any handheld mobile device, to every professional within the group selected. Each of these professionals will then have the ability to send correspondence containing text and/or attachments in the form of images, PDFs, spreadsheets, or CAD files. Also, the RFI would be equipped with an urgency indicator that could send additional information pertaining to the estimated completion date of the project and the impact the RFI will have on downstream trades. Reminder notifications could also be automatically generated while the RFI is still outstanding in order to encourage prompt response times, and a specific indicator could be sent out once the final response is submitted and the RFI has been closed.

The RFI Discussion Forum versus the Principles of Lean Construction

In 1992 Lauri Koskela wrote a technical paper defining lean construction and developing 11 principles that can be used as a guide to making a construction process more efficient. Lean construction is a project delivery system with the goal of meeting the client's needs while using fewer resources[3]. The 11 principles of lean construction that Koskela[4] suggests are as follows:

1. Reduce the share of non value-adding activities
2. Increase output value through systematic consideration of customer requirements
3. Reduce variability
4. Reduce cycle time
5. Simplify by minimizing the number of steps, parts and linkages
6. Increase output flexibility
7. Increase process transparency
8. Focus control on the complete process
9. Build continuous improvement into the process
10. Balance flow improvement with conversion improvement
11. Benchmark

Many of these principles can be applied to the use of the RFI discussion forum. For example, when a project converts from the traditional method of submitting RFIs to the RFI discussion forum, the RFI will no longer have to travel through a complex communication sequence which will create less emails being forwarded by individuals that are not adding any support to developing the solution. Fewer emails from superfluous individuals can also be directly correlated with reducing non-value adding activities, minimizing the number of steps, parts and linkages, and reducing variability and wasted time. Additionally, the fact that each entry can be seen by everyone on the team encourages each team member to be clear and accurate in their responses; this consequence can be directly correlated with Koskela's principle on transparency and building continuous improvement into the process. Furthermore, there will be less time wasted while an email is sent to one professional only to be delayed in the inbox of another professional, which could greatly reduce the overall cycle time of the RFI process.

And further still, the discussion forum can create the opportunity for the professionals to overcome challenges together and incorporate these best practices into the next project, which is considered by Koskela as benchmarking.

The Simulation

In order to test the efficiency of the standard RFI method versus the proposed RFI discussion forum, a simulation was developed. Simulations are powerful tools used to address diverse learning styles by engaging the learners in hand-on activities[8]. Additionally, simulations can assist in the development of teamwork, cooperation, production system design, and dependency and variation[8]. Furthermore, the simulation presented below will encourage the exploration of the potential that the proposed RFI discussion forum presents as well as any areas for improvement. Lastly, this simulation can be used to reinforce the value of clear communication, and to emphasize the effect that delays will have on each individual trade as well as the overall project.

To start this simulation there will need to be 5 or 6 team members. One team member plays the role of the trade foreman, one team member is the superintendent, one is the architect, one is the project construction manager, one is the inspector, and one is the structural engineer. During the test run of this simulation the following parts were used: a building platform with a north arrow, 8 Legos, 6 pencils, a stop watch, blank paper, step by step photos of 2 different structures, and 2 sets of written instructions on how to build each structure. There are 2 phases to this simulation: scenario 1 and scenario 2. In each scenario the set of written instructions is provided to the contractor who is tasked with building the structure from the Legos. The instructions are written in a manner as to elicit questions from the foreman in order to simulate the RFI process. Only the structural engineer will have access to the step by step photos of the structure being built. The contractor will not be able to proceed to the next step in the instructions until he obtains the necessary information from the structural engineer. These scenarios are meant to mimic a typical design-bid-built communication sequence; the first scenario represents the standard RFI process while the second scenario represents the method of the RFI discussion forum

In the first scenario that is played, the trade foreman will be given the set of instructions for structure number 1. The foreman is responsible for building the structure completely and correctly, as it will be inspected by the inspector at the end of the simulation. The players are instructed that no verbal communication is to take place, only written, simulating communication through computerized email messages. There are 7 very vague, non-detailed instructions for the construction of structure 1 that is given to the foreman. The step-by-step visual images are given to the structural engineer. Once the timer is started, the foreman will begin to build the structure. When the foreman is faced with an instruction that is unclear, he must prepare and send a mock RFI to the superintendent. To do this, the foreman must create a simulated email by writing out the request for information on the paper provided and then send it (or hand it) to the superintendent. After the superintendent examines the validity of the mock RFI, he will either forward the email to the project construction manager or send it back to the foreman for additional details. The construction manager will perform the same type of review to the mock RFI and will respond in a similar manner, either by sending the question back for additional details, or by forwarding it to the architect. The same procedure will be followed by the architect who will also review the question and forward it to the structural engineer. Once the structural engineer has the RFI, he will have to look at the photos made available to him and come up with either a solution to the question or another question to clarify what the foreman is asking. The solution can be in the form of written instructions or hand drawn schematics. The structural engineer will then send the response back through the communication chain until it reaches the foreman. The foreman will then need to decide if there is enough information to resolve the problem or if further information needs to be requested. If that step of the instructions can be completed, the foreman will move on to the next step and continue the process as before.

The instructions for structure 1 are as follows:

1. Lay the building platform on the table with the north arrow pointing up
2. Lay the light grey Lego piece flat on the platform
3. Lay the 2 purple pieces on either side of the light grey piece
4. Place the grey piece across all 3 existing pieces
5. Place the long black piece at the end, connecting the purple pieces
6. Place the black L-shaped piece on top of the long black piece
7. Place both triangle pieces on either side of the dark grey piece

Once the structure is complete, the timer will stop and the inspector will examine the structure, comparing it to the visual images provided. The structure that is to be built can be seen in the figure below.

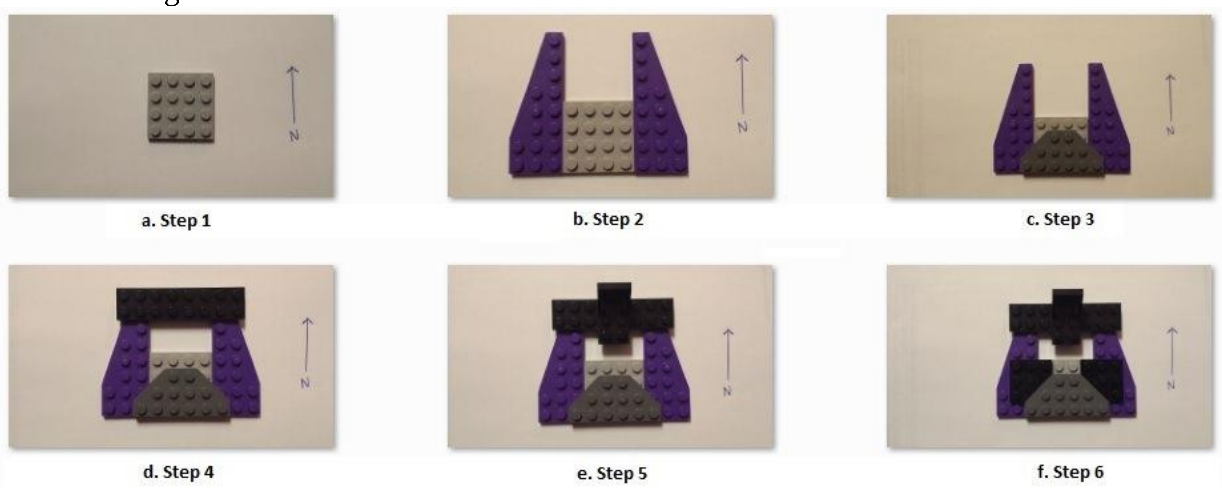

Figure 2.a-f - Scenario 1 - Visual Building Instructions

In the second scenario, the foreman will be given a set of instructions to build structure number 2. As before, the foreman is responsible for building the structure completely and correctly, as it will be inspected at the end of the simulation. The players are instructed that no verbal communication is to take place, only written, simulating communication through discussion forum messaging. Structure number 2 is proposed using the same 8 Legos but with a different set of instructions that are, again, written in a manner as to elicit questions from the foreman. The structural engineer will be given the visual images in order to respond to the mock RFIs that will be sent from the foreman.

Once the timer has started the foreman will begin building the structure. As in scenario 1, the foreman will immediately need further information before he is able to complete the construction of the structure. In this scenario, once the foreman writes out the question it is placed face-up in the middle of the table, making the mock RFI immediately accessible to everyone else on the team. At that point, anyone with a question, comment or concern is able to respond, in writing, to the foreman's initial question. Any response to the mock RFI is also placed face-up in the middle of the table, making it immediately accessible to the other team members. The project construction manager is advised to oversee the comment responses being made and to encourage certain teammates to contribute their ideas. If the structural engineer responds to the mock RFI, even if it's with additional clarification questions, the foreman will be able to see these questions right away and should be able to respond quickly, either with additional questions or by closing the RFI. To simulate the RFI discussion being closed the foreman will remove the pile of responses from the center of the table and set them aside. Once the foreman has enough information to complete that step in the list of instructions and that mock RFI is closed (set aside), the foreman will move on to the next step in the instructions.

The instructions for structure 2 are as follows:

1. Lay the building platform on the table with the north arrow pointing up
2. Lay the long black piece flat on the platform
3. Place the triangle pieces at either end
4. Place the tips of both purple pieces under the triangle pieces
5. Place the black L-shaped piece on top of the long black piece
6. Place the light grey piece on tip of the chair piece
7. Place the dark grey piece under the light grey piece

Once the structure is complete, the timer will stop and the inspector will examine the structure, comparing it to the visual images provided. The structure that is to be built can be seen in the figure below. Each of the team members is requested to compare and contrast the 2 scenarios and discuss what could be learned from each.

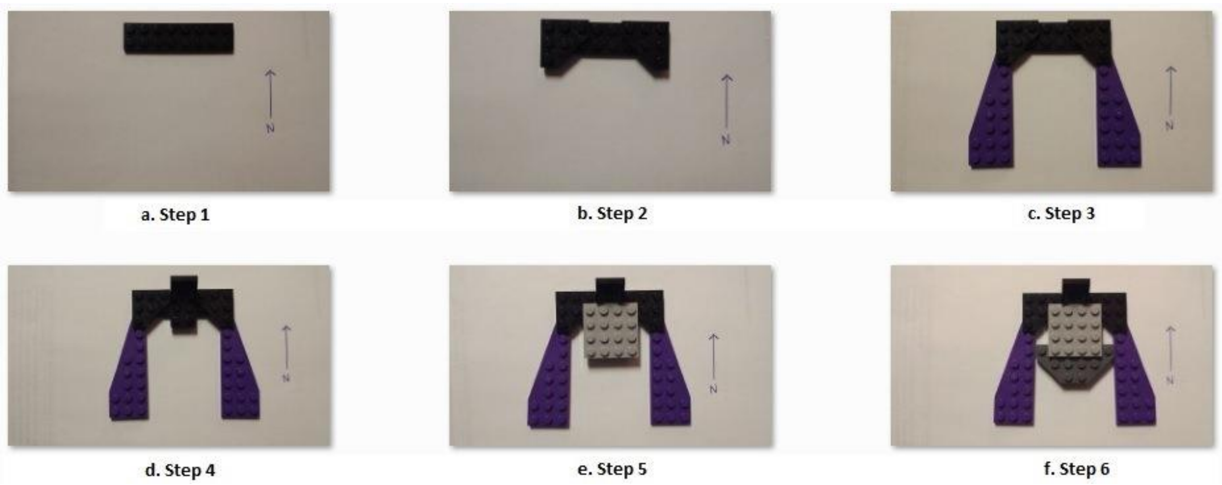

Figure 3.a-f - Scenario 2 – Visual Building Instructions

Results

While testing this simulation, each scenario was played out using the same 5 people. In the first scenario the structure was built correctly and completely in 27 minutes and 35 seconds.

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The second scenario was built correctly and completely in 15 minutes and 49 seconds. This data suggests that the RFI discussion forum could be 42% faster than the traditional methods.

There will be a few variations, obviously, between this simulation and the actual RFI process. First, any program that is made with the intention of solving issues for the user is only as good as the operator of that program. In other words, if the team members of the project are not on board with the idea of using this tool as it is meant to be used then the efficiency issue within that project cannot be rectified. Also, the structures actually being built will come with a set of detailed schematic drawings that will be numerous pages thick, which will add more complexity to the process. Furthermore, there could be many more stakeholders or decision makers involved on a project, which could add increased variability and complexity to the process. However, this simulation confirms that the RFI discussion forum does support many of Koskela's principles of lean construction such as reduced non-value adding activities, reduced cycle times, and increased transparency.

Additionally, this simulation could be used as a great learning tool. Students and professionals that complete this simulation should be able to better appreciate the value of clear and direct communication as well as enhance coordination techniques in order to produce the desired result in the most efficient manner.

Conclusion

The RFI process plays a huge role in the construction industry. Everyday RFIs are submitted, and many construction teams have felt the strain that an outstanding RFI can have on a project and its schedule. For these reasons and more, it is imperative that the RFI process flows as smoothly and efficiently as possible. Fortunately, there are a few simple strategies that construction management teams can follow in order to help ensure that any impending RFIs will be taken care of effectively and promptly. Reducing the number of people that the RFI has to pass through, making the information as clear and concise and transparent as possible, and opening up the flow communication are but a few options available to try to reduce the RFI cycle time. As seen in the information provided, the proposed RFI discussion forum employs all of these strategies. This forum could change the pace of the construction industry and enhance the communication and coordination skills amongst the professionals.

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A Proposed Individualized Electronic Monitoring Sensor to Track Sleeping Patterns and Improve its Associated Health Outcomes

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Abstract:

Heart attacks and cardiovascular disease overall is the leading cause of death in the United States. It accounts for about 600,000 deaths each year. One of the key risk factors for cardiovascular disease is hypertension, or high blood pressure. Currently there are 67 million people who suffer from hypertension in this country alone. The costs of treating hypertension itself are over $47 billion annually. Thus, finding cost-effective and innovative solutions to combating this problem are vital. Blood pressure monitors are used to estimate arterial cuff pressure in the arms of a patient to deduce the systolic and diastolic pressure to measure the heart work load. By using existing monitoring techniques coupled with the use of individual patient health data informatics, personalized and custom-tailored health recommendations can be made to patients to treat their hypertension in their daily lives. Lifestyle effect modifications, such as changing sleep postures and what effect it may have on blood pressure, can be measured and recorded in real time to determine what effect one's behavior can have on a person's health. In this study, four specific sleep postures were analyzed to determine if different postures had any effects on one's blood pressure. The initial findings of this pilot study suggest that differing sleep postures do indeed have effects on blood pressure and this may have important implications for the treatment and control of hypertension in patients. Sleeping on the right side was associated with lower levels of blood pressure and sleeping on one's stomach was associated with higher levels of blood pressure from the participants of this study. This data suggests that further studies, such as a rigorous randomized control trial, needs to be conducted to determine the association between blood pressure and sleep postures on the population level. This study also proposed the creation of a wearable biosensor that could be used to determine the blood pressure in people. Using a modern day data driven approach, the information complied by this device such as blood pressure levels could be evaluated by health professionals and patients to determine if one's sleeping habits are affecting ones risk for hypertension and heart disease. Furthermore, this device could then also provide real-time feedback to the patient during their sleep to help them choose the best sleep position for their overall health and well-being.

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Introduction:

Cardiovascular disease is the leading cause of death in the United States. It accounts for about 600,000 deaths each year. It is the leading cause of death of all diseases in both men and women in the United States [1]. One of the most critical risk factors for heart disease is hypertension or more commonly known as high blood pressure. Currently there are about 67 million, or about 1 in 3 people, who suffer from hypertension in America[2]. The costs of treating hypertension alone exceed $47.5 billion dollars each year in the United States. Thus, finding cost-effective and innovative solutions to combating this problem are vital.

Current blood pressure monitoring systems make use of natural physical properties such as wave oscillation to measure the blood pressure of the body to create devices such as the sphygmomanometer. Over the past few decades, there has been a transition from analog to digital blood pressure sensors. For the most part, these sensors attempt to estimate the arterial cuff pressure in the arms of a patient to deduce the systolic and diastolic pressure to measure the heart work load. This provides a good proxy estimate of blood pressure and whether or not a patient is at high risk for hypertension and its related cardiovascular diseases.

The role of sleep is an important aspect of the human existence. A person spends approximately 1/3rd of their lives in a state of sleep. Thus, finding a point of intervention at such a critical juncture of the human life would be worthwhile investigating. Therefore, the aim of this study was to see if sleeping patterns played a role in hypertension and other cardiovascular events. Specifically, we wanted to see if we can detect any noticeable differences in the common sleeping postures: stomach, back, right side and left side. If any differences in blood pressures could be found in a phase I type of study (involving around 20 people), this may be a potential area of intervention where an engineering approach could be used to enhance the sleep experience in the short run but also enhance one’s health by monitoring blood pressures of each individual throughout their sleep.

The review of the literature of sleep has primarily focused on the mental health aspects. For instance, the relationship between sleep patterns and mental concentration show the necessity of sleep for human beings. Furthermore, a lot of studies in the fields of biology and psychology have focused in the role of REM, rapid eye movements, in sleep.

In essence, the function of sleep is method for the body and brain to recuperate and rest. Without it, the human body, which can be seen as a system of intricate biological machinery would be damaged or working at less than ideal

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conditions which limits the functionality of the human body overall. The systems of the human body such as the cardiovascular system, the renal system, the sympathetic & parasympathetic nervous system, and immune system all need this period of rest for overall body to function.

However the relationship between blood pressure and sleep postures have not been heavily studied in the past. There are some interesting epidemiological studies assessing the relationship between the treatment of sleep apnea, a sleep disorder characterized by gaps in breath or the prevalence of shallow and infrequent breathing patterns during sleep and blood pressure. Hoyos and his team determined that treating sleep apnea does indeed reduce central and peripheral blood pressure in a randomized control trial[4]. Chen also determined that obstructive sleep apnea is associated with arterial stiffness in some stroke patients[5.]

There have been some historical and traditional advice for certain sleep positions. Some of these sayings are found in the Prophetic tradition of the Muslim faith in which the Prophet Muhammad advised his people to position themselves on the right side when going to sleep. He also discouraged a person from sleeping on their stomach[6].

While there is no quick solution to addressing the topic of best sleeping posture, it could be hypothesized that sleeping on the ride side would indeed be the best since the pressure load on the heart would be the lowest. Sleeping one's stomach would probably have the opposite effect. While various sleeping positions are related to other varying health outcomes such as concentration, stomach ulcers and especially stiffness and muscle strain, finding a potential association between blood pressure and sleep posture would be significant. These findings could then be used to create an individualized monitoring device that could prompt instant feedback to the person and potentially offer the best sleeping patterns to improve one's overall health.

Methods

The purpose of this study was to determine if there is any sort of relationship between sleeping postures and blood pressure. Therefore, the scope of the study was to design a pilot Phase I study in which approximately 20 peoples' blood pressure was monitored using a typical electronic arterial blood pressure monitoring system. The test subjects were monitored at four of the most common sleeping positions: back, stomach, right side and left side (see Figure 1). Each reading for systolic, diastolic and pulse rates were recorded three times for each sleeping position.

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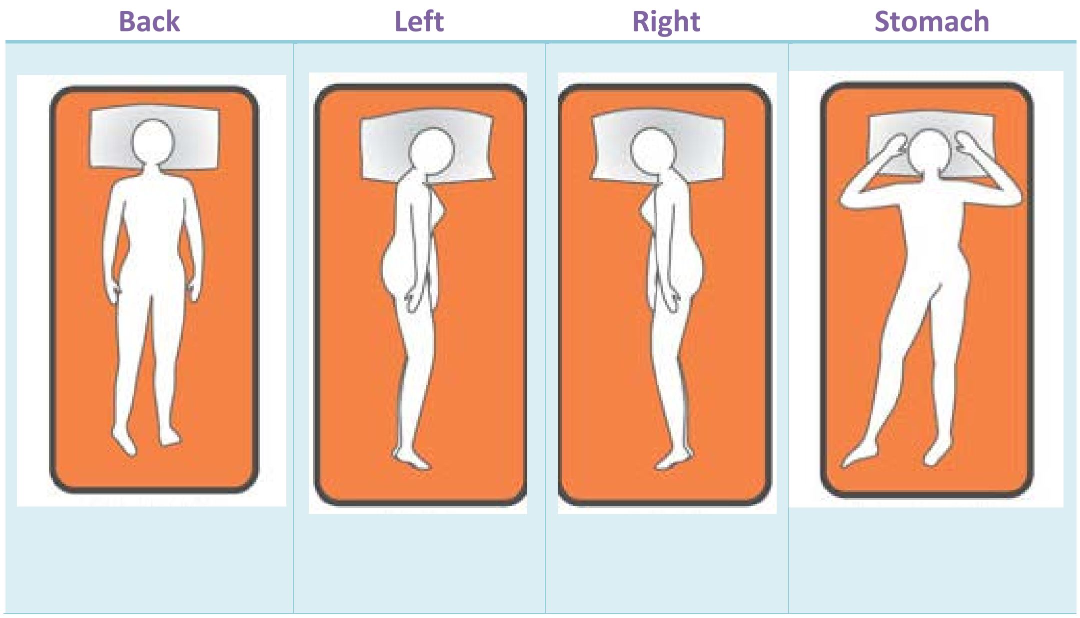

Figure 1: Layout of the 4 sleeping postures

The test subjects themselves serve as their own control in that we merely wanted to see if there were differences in blood pressure in each subject for each of the four positions. Therefore, the data that will be compared will analyze potential differences in each person for each position. If a similar trend can be seen across all 20 patients, this would indicate that this is a potential area of treatment.

This would help justify whether or not the study had the potential for efficacy or therapeutic benefit. If so, Phase II of the study will then be conducted on a larger scale to determine effectivity, whether or not a particular sleeping position has potential benefit to reduce blood pressure at the population level.

Findings/ Data:

KEY

R= Right	**L=Left**	**B= Back**	**S= Stomach**	**Sys= Systolic**	**Dia= Diastolic**

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The following results are average systolic and diastolic blood pressures and pulses (on the Y axis) of each of the twenty participants (on the X axis) in the experiment. Systolic and diastolic are recorded in millimeter of mercury (mm Hg).

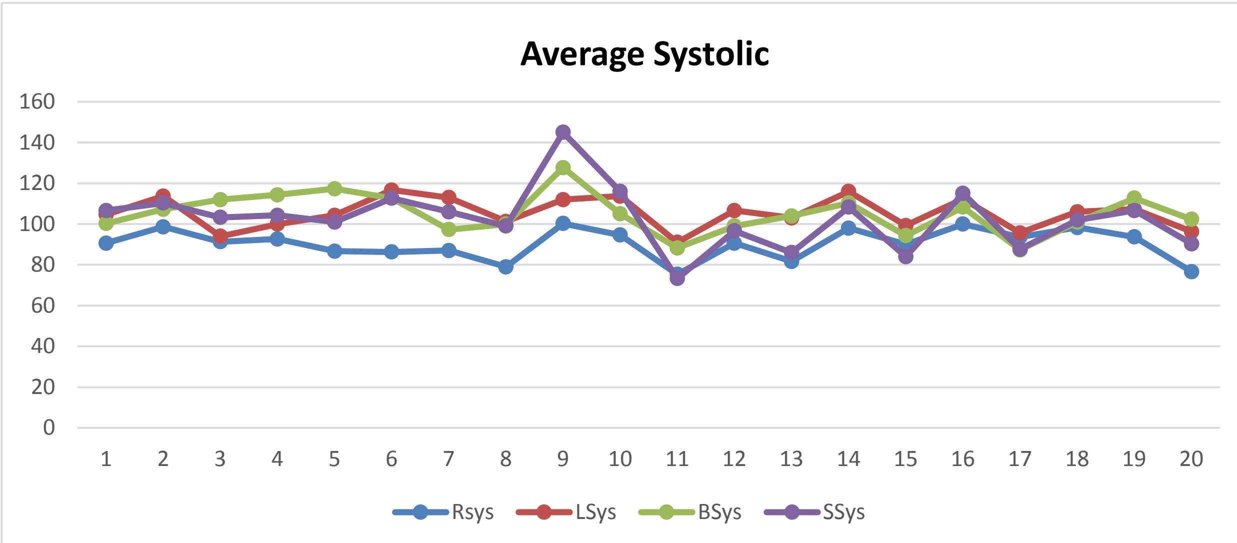

Figure 2: In almost all the participants, the right systolic (RSys) blood pressure, which is the blue line, was the lowest.

Participant	Rsys	LSys	BSys	SSys
1	90.67	104.67	100.3	106.67
2	98.67	113.67	107.3	110.3
3	91.3	94	112	103.3
4	92.67	100	114.3	104.3
5	86.67	104.3	117.3	101
6	86.3	116.67	112.67	112.67
7	87	113	97.3	106
8	79	101.3	100	99
9	100.3	112	127.67	145
10	94.67	113.67	105	116
11	75.3	91	88.3	73.3
12	90.67	106.67	99	96.67
13	81.67	103	104	86
14	98	116	110.3	108.3
15	90	99.3	94.3	84
16	100	112.3	108.3	115
17	93.67	95.67	87.3	87.67
18	98.3	106	101	102
19	93.67	107.3	112.67	106.67
20	76.67	96.3	102.3	90.3

Figure 3: Average Systolic Pressure Table

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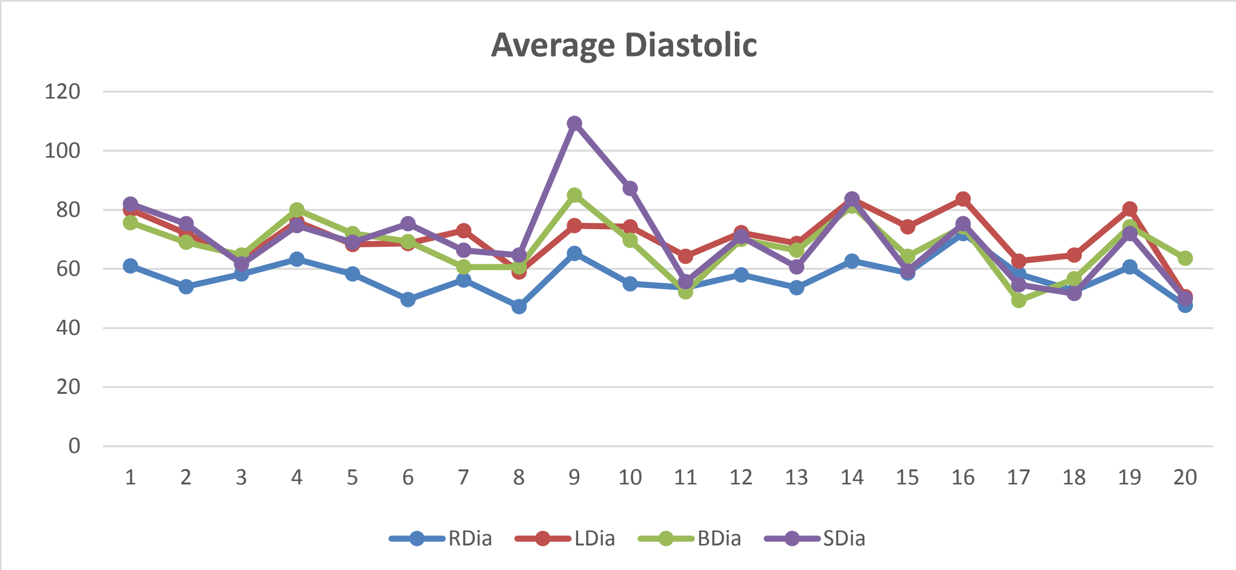

Figure 4: In almost all the participants, the right diastolic (RDia) blood pressure, which is the blue line, was the lowest.

Participant	RDia	LDia	BDia	SDia
1	61	80	75.67	82
2	54	72	69	75.3
3	58.3	63	64.67	61.67
4	63.3	76	80	74.67
5	58.3	68.3	72	69
6	49.67	68.67	69.3	75.3
7	56.3	73	60.67	66.3
8	47.3	59	60.67	64.67
9	65.3	74.67	85	109.3
10	55	74.3	69.67	87.3
11	53.67	64.3	52.3	55.67
12	58	72.3	70	71
13	53.67	68.67	66.3	60.67
14	62.67	83.67	81.3	83.67
15	58.67	74.3	64.3	59.3
16	72	83.67	74.3	75.3
17	58.3	62.67	49.3	54.67
18	52.67	64.67	56.67	51.67
19	60.67	80.3	74.3	72
20	47.67	50.67	63.67	50

Figure 5: Average Diastolic Pressure

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From the data, it was found that in most subjects, the right side systolic blood pressure was lower than their other systolic blood pressures (back, left and stomach). The same trend was also seen for diastolic blood pressure. Most participants exhibited lower right side diastolic blood pressure than in any other positons (back, left and stomach). Therefore, these trends suggest that a possible point of intervention can be further studied to determine the effects of sleeping positions on blood pressure.

Conclusions:

From the preliminary findings of this pilot study, the trends showed that there was a decrease in blood pressure levels with the varying sleep positions. From the data, it was also seen that sleeping on one's stomach was associated with the highest levels of blood pressure while sleeping on one's right side was associated with the lowest levels of blood pressure.

For the future, this study needs to be taken into Phase II testing in which a large sample size of patients are assessed in a randomized control trial. The prescribed intervention could be the recommendation to sleep on the right side and the control group could just be left as with general sleeping advice. If a signification association can be seen in such a large scale epidemiological study, this would further enhance the notion that sleep posture is a point of intervention in the human lifestyle that could be modified to better health outcomes such as hypertension, heart attack and other cardiovascular incidents.

Future Proposal:

The analysis of this study yielded the need for better tools that could be used in assessing blood pressure and other biomarkers pertaining to the study of sleep. I would propose that a personalized portable electronic sensor could be devised in which real time data would supply feedback back to the user when it comes to sleeping patterns and other health behaviors.

This century is being dubbed as the era of the digital health revolution. The concept of digital health encapsulates the ideals of customized personalized data driven approach to health. By integrating big data analytics and using informatics to customize individually tailored medical advice for each individual, we can ensure that the best health advice and tools are being supplied to patients in time and cost efficient manner that potentially offers the greatest benefits to humankind.

A wearable sensor could be created that incorporates many of these ideals to create a biosensor that would be placed on the patient before they fall asleep. This sensor would be connected to a database that has the relevant health informatics data for this patient and the appropriate recommendations for the patients. In the case of sleep posture and hypertension, the sensors could send a signal, such a beeping noise or a vibration to the patient to alter their positon

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during the night. The algorithm for this program could be used to devise an a mobile application which would keep track of all these data and supply the patient and their physician with the necessary information to determine sleep position is best to keep blood pressure levels at a normal range. This surveillance tool could then be manufactured for the general public who could then take better care of their health.

The costs of healthcare in the United States account for almost 20% of the total US budget. Therefore it’s absolutely imperative that we find ways to better the health outcomes of all people by focusing on preventing diseases before they become bigger problems. However, devising the right tools and technology in the field of medicine and public health has been a slow process. The creation of novel new tools for surveillance and detection are key to improving health outcomes and reducing costs. The field of engineering plays a big role in devising the proper tools that healthcare officials and patients need to monitor and improve their health. This collaborative multi-disciplinary approach must be fostered across academic and professional disciplines as we as a society continue to attempt to solve the great challenges of the world.

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The Paradigm Shift of Coursework Development Through Industry Partnership: An Account of the Development of a Course in Structural Engineering Masonry Building Design

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Abstract

Academic partnering with industry is a paradigm shift that has taken many forms. The more recent discussions in this partnering paradigm shift concern the influence on the curriculum by the partnership. By partnering with industry during course development, up-to-date, and direct information on the current market place can be incorporated into the curriculum. Information that is typically gained through an internship can be gained by all students in the classroom. For engineering students of the built environment (e.g. civil, structural, or architectural), a recent partnership with industry identified a shortcoming in the traditional or typical structural engineering program. Typical structural programs usually offer students only two design courses – steel and reinforced concrete. However, the partnership identified the fact that when considering the built environment the majority of new construction is for structures around three stories or less. Such buildings tend to favor timber/masonry as the economical choice. And the consulting structural engineering profession has indicated a strong benefit for the student entering the market place who have had these preferred materials design courses. Industry has also indicated that students who have a more applied science and/or hands-on learning experience (robust) adapt quicker to work place environment. Considering the market place input from the partnership and wanting to offer students a more robust course offering, an engineering course in masonry design was developed with direct input from a professional industry association. Emphasis was placed on current industry practices – testing, quality of construction, and theory to code application. In addition, a mechanism was put in place for market place assessment over a 5 year span. This paper gives an account of partnering in course development.

Motivation

The more recent discussions in this partnering paradigm shift concern how industry could or should influence curriculum. At the 2013 Conference of American Society for Engineering Education (ASEE), Chinchilla investigated the question as a matter of ethics and saving industry training costs [1]. Ahzar et. al. noted how the academia-industry partnership can be used to advance the knowledge base in construction management education [2]. This paper demonstrates the positive affect of an academic-industry partnership and how the curriculum and teaching is

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directly influenced by the partnership – course selection, content, delivery method, and availability of resources.

The mission of the architectural engineering program at Cal Poly – San Luis Obispo is to educate students to enter and be successful in the practice of structural engineering, with an emphasis in seismic design. The program prides itself on going beyond traditional civil engineering structures education and thus took advantage of the opportunity to partner with industry in setting up a non-traditional curriculum.

Traditional structural engineering design curriculum has courses dedicated to steel and concrete only. Occasionally a course in timber can be found, but it is not common. The lack of course work in masonry and timber is not adequately supported when one considers that the majority of building construction is three stories and under, and the most common structural material for those building is masonry and timber. In addition, the Structural Engineer licensing examination requires the candidates to answer and pass design (breadth and depth) problems in timber/masonry besides steel and concrete[3].

The building industry has been proactive in meeting the changing needs and demands of society through design, engineering, and construction practices that result in safe, economical and sustainable structures. The American Institute of Architect (AIA) has taken a next step in sustainability by uniting the building industry with a commitment to resilient design[4]. Just as the building industry is proactive, engineering education must also be. One proactive step is to offer additional design courses in resilient structural materials.

When considering the prevalent use of masonry; the preparation of engineers for the masonry licensure questions; and masonry's high resilient quality (the next step in sustainability), a masonry design course is the obvious proactive step and would create a more robust engineering education. The authors partnered with industry in developing a curriculum for masonry design. The goals for the curriculum were to be efficient, pertinent, and give students practical experiences (i.e. hands-on experiences). In addition, it was the goal to format the course and its resources in such a manner that other institutions could easily adopt the course and offer students a more robust practical engineering education. A mechanism for assessment of student performance in the market place was also considered.

The Course Development

The partner for the course development was the Concrete Masonry Association of California & Nevada (CMACN) **[1]**. The organization serves as the leading concrete masonry data clearinghouse in the western states and facilitates up-to-date masonry information gathering and dissemination. As an example, the CMACN are publishers of the *Design of Masonry Reinforced Structures*[5] – a textbook that is appropriate for the classroom and used as a reference by practicing engineers. Included in the book are several practical design examples and aids.

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The partnering was able to address the issue that the real world rarely reflects the “perfect” examples used in the theory of academia. It was agreed that it is best for the student to be introduced to a topic using the “perfect” examples of theory, but as quickly as possible the real world issues and challenges need to be brought into the teaching. The best way for the students to understand this is through hands-on experiences, with the partner providing guidance, access to industry, and resources.

The partnership lead to a series of goals for the curriculum development. These goals would set the frame work. The goals identified were:

- to incorporate hands-on practical student experiences where possible;
- interweave the governing building code with the theory;
- format the course such that other universities can readily adopt the course; and
- to provide a mechanism for assessment in the market place.

Hands-On Student Experiences

The industry partner was instrumental in planning the hands-on curriculum and providing the resources. All issues and possible problems in creating the hands-on experience were able to be identified and addressed by the industry partner. For faculty who are not intimate with industry, the partner was able to eliminate any guess work on the part of the instructor. In addition, the industry partner coordinated the delivery of materials and the availability of a professional masons.

Four student hands-on experiences were created to enhance and underscore construction quality on masonry properties and behavior. The four experiences were as follows:

Student Hands-On Experience 1: *A tour of a concrete block manufacturing plant to reinforce the industry terminology*. The tour gave the students access to an industry professionals who were able to convey the information and issues required for an engineer to assure their specifications can be met. For example, reduced cement content in a block is a sustainability measure that is becoming more common. The students were able to hear directly from the plant manager about the issues and requirements to reduce cement content. Another example was the students were able to see a whole stock of masonry products and feel the weight of different block sizes which is very important experience in masonry design. Below is a picture of the students at a local block manufacturing plant.

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Figure 1: Students of the Masonry Design Course at a local block manufacturing plant.

Student Hands-On Experience 2: *Actual mixing of mortar from raw ingredients and construction of a masonry test prism.* Through this experience the students begin to see how the written specifications can affect the actual construction. For example, what is meant in the specification, "to add enough water to make a workable mix?" Below are a sequence of pictures showing mixing of mortar and building test prisms.

Figure 2: Dry Ingredients

Figure 3: Adding Water

Figure 4: Proper Mix

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Figure 5: Buttering the Block Figure 6: Level the Prism

Student Hands-On Experience 3: *The construction of a masonry wall with a professional mason*. By working directly with a professional mason, the student saw how the paper design actually transferred to reality. Such issues as dimensions (conform to block unit dimensions) and reinforcement bar clearance can have a great negative impact on project if not properly considered in the paper design (see Figure 7 – next page).

Figure 7: Student work directly with professional masons

Student Hands-On Experience 4: *The testing of prisms.* The prism test allowed the students to gain an understanding of code values versus actual. Since the students constructed the prisms, the students were able to witness how the quality of construction affected the compression values. The students were also able to determine the compressive strength of mortar cylinders and individual blocks and to compare the individual strengths to that of the prisms (assembly) tested as shown in Figure 8 below.

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Figure 8: Compressive testing of masonry prism

Governing Codes and Theory

To emphasize the practical application of the course, the textbook required for the course was written by adjunct college professors who are practicing structural engineers. The content of the textbook quickly goes from the theory of masonry design to the implementation of the theory through code application. In review of the textbook, the partnership was able to identify the need for component of the course to include “load flow”.

It is typical for design course to present students with design problems that have loading given. Again, this is can be used for introducing a concept, but it does not reflect reality. Determining the loading is a major part of structural design, and the partnership agreed the student should be made known of this fact. A component of the course lecture included “load flow”.

The International Code Council (ICC) reference document for the masonry building code (TMS 402) [2] was integrated throughout the curriculum. The code book was provided to each student by the industry partner free of charge. Figure 9 below show the course text books which were donated by the industry partner.

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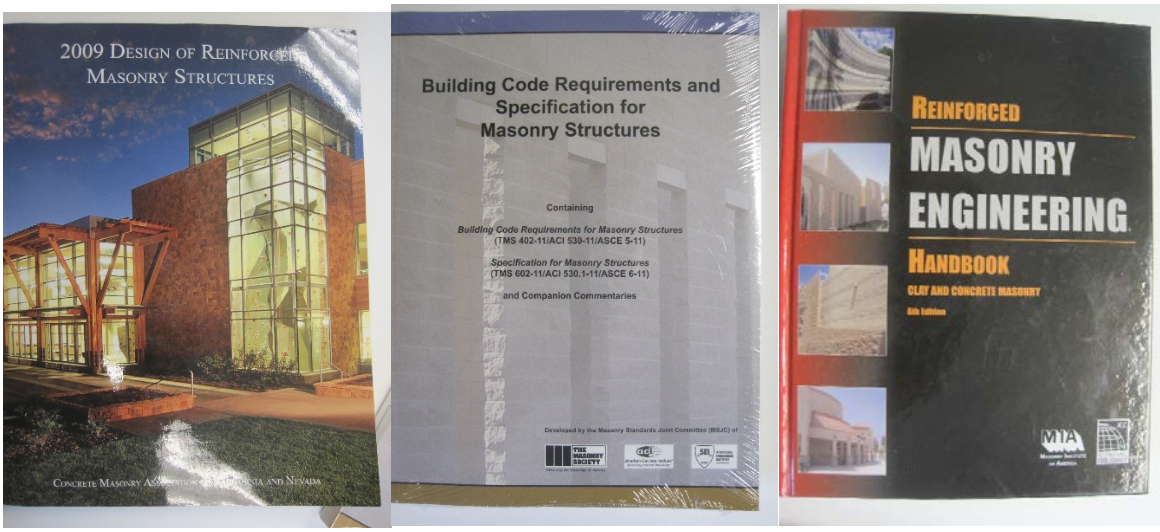

Figure 9: Course Textbooks

Formatting the Course

One of the goals of the course development was to format the course documentation such that the course could easily be incorporated by other universities. By including a partner in the course development, an outside pair of eyes was available to assure the course did not include nuances of our own facilities and department practices.

The course documentation included:

- a syllabus that can conform to the semester or quarter system and 2 or 3 unit course;
- board notes for the instructor for each lecture;
- power point presentations for non-traditional topics and hands-on activities;
- homework and exams examples; and
- resources required for hands-on activities.

The industry partner committed to providing the resources to the students.

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Mechanism for Assessment in the Market Place

The benefit in creating a curriculum with an industry partner is the ability to identify the market place components that have changed over time and how best to benefit the student education. This partnership was able to identify a need for a more robust course offering to "keep up" with the changes in sustainable design and to allow the engineering student to have a bigger impact in the market place. Since the market place is continually changing, the impact of the design course has to be assessed. Assessing student success in the market place is a long term task. The industry partner is aware of this and has committed resources and funding to assist universities who would like to participate in adding a yearly course offering in masonry design and assessing the student success in the market place [1].

The template for implementation is to provide participating universities with course materials, hands-on experience resources and funding, such that time and financial impacts are minimized. The template for assessment is to meet every year (for five continuous years) during the summer and come to a consensus.

Conclusion

In the development of the Masonry Design course, a current market place component of education was brought directly into the curriculum through hands-on experiences and practical application of classroom theory. The industry partner was able to identify issues for implementation and readily commitment to providing necessary resources – resources beyond the traditional classroom. In this case the resources included building materials, coordination administration, access to industry facilities, code books, textbooks, and funding.

In regards to the actual course content, non-traditional classroom ideas were explored and a framework for development was created where academic theory was used to introduce a topic and real world application used to apply the theory. The framework for Masonry Design course was as follows:

- Incorporate hands-on practical student experiences where possible.
- Interweave the governing building code with the theory.
- Disseminate information by formatting the course for use by other universities.
- Provide a mechanism for assessment in the market place.
- Design curriculum with the knowledge and resources from supporting industry.

The industry partnership for the Masonry Design course has shown success to date. The market place assessment is for further research - contact CMACN [1] for additional information and to participate.

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The annual summer meetings, will be used as a venue to discuss course improvements such as learning management systems and possible future areas of consideration like hybrid and/or online components of the class.

End Notes

[1] Concrete Masonry Association of California & Nevada; 6060 Sunrise Vista Dr., Suite 1990, Citrus Heights, CA 95610; http://www.cmacn.org/

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Flexible and Enduring Engineering Education Built on the Basics and Reinforced through Practical Problem Solution

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Abstract

Students in any discipline learn and retain more when exposed to material that stimulates their interest. In engineering, all students must understand certain basics in mathematics, physics, or the concepts of their chosen discipline. A student may be able to memorize or otherwise master an advanced concept without the basic knowledge to verify the technique or result. Theoretical concepts in early undergraduate courses are sometimes difficult to comprehend when a student may not see a direct application of the material to a practical system. Often students are required by instructors to apply a particular software routine or code they do not understand. When this occurs, the student becomes a data-in-data-out technician and ceases to be an innovative engineer who can solve problems. Students must understand the basics before they can understand more complex concepts. There appears to be two compelling reasons why some engineering curriculums are not stressing the basics. First, many years ago the computer explosion made solutions much easier and primary while the basic concepts necessary for the solution method became secondary. The students then believe all knowledge required for the solution of problems is stored in the computer and does not need to be known or understood. Second, the engineering educators became fixed on research and assumed their students wished to pursue advanced degrees. The fallacy of the assumption is most students want to seek employment after graduation and utilize the undergraduate education just received. This paper discusses the above postulates and proposes some solutions and a system of practical courses to stress and utilize the basics for enduring engineering education.

Introduction

Observations of some tenured engineering educators who teach undergraduate design courses indicate a concern over the lack of emphasis on basic knowledge in the engineering curricula. In this document, the authors list some of these issues for consideration in undergraduate programs. Apparently, some prerequisite courses in engineering disciplines emphasize the theoretical approach without proper basic knowledge or practical reinforcement. It is often assumed students thoroughly understand mathematics, physics, and basic discipline specific knowledge before advanced theoretical techniques are introduced. Students can master advanced techniques without understanding the basic principles or limitations of these concepts. In many design courses throughout academia, students are given previously developed routines or programs to utilize in problem solution. Even in industry/academic cooperative programs, students are instructed to use computer routines that merely accept and return numbers. These programs do not encourage initiative or innovation and are usually not motivational to the student. If students

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do not understand how or why these computer aides calculate results, the bounding conditions cannot be justified and the output cannot be verified. When asked, the student may reply, “I don’t need to understand how to accomplish a task, I can just google it”. In this case all the intelligence is in the box under the desk and the computer on the student’s shoulders is not designing the object. This seems to be more prevalent with the explosion in our technology and communications. Advances in our technological tools are incredibly useful but we must heed a caution by a very intelligent individual named Albert Einstein when he is reported to have said, ”I fear the day that technology will surpass our human interaction. The world will have a generation of idiots”.

Advancements in technology have allowed tasks that once took days or weeks to be accomplished now can be completed in minutes. These time saving computer methods open up a vast new world of nearly infinite possibilities that are accompanied by some often overlooked consequences. If these drawbacks are not considered and addressed, the human interaction and reasoning capability may be lost. Young engineers fresh from a higher education program that does not stress the basics may be able to generate solutions using purely theoretical or computational techniques but lack the practical knowledge to determine the validity of a result or to modify an existing solution method to meet the parameters of a different environment. Using the time-saving computational techniques not only encourages students to dismiss a need to learn and retain but also stimulates faculty to lose focus on teaching basics and focus on researching and applying advanced techniques in the classroom before the students have the capacity to absorb these concepts. It seems most faculty now are focused on preparing the students for advanced education on a masters or doctorate level instead of preparing then to be successful as a freshman engineer in the industry. Many of our universities have lost focus on educating the undergraduate students and focus only on the graduate student who contributes more to faculty gratification and institutional prestige which is rewarded with grants and funds. The undergraduate students are taught by the teaching assistant graduate students while the faculty are working with the graduate level students to publish. Knowledge discovery is wonderful and necessary at an institution of higher learning, but only effective when in balance with teaching practices that prepare a student for lifelong learning whether in a laboratory or on the assembly line floor.

The purpose of the examples and proposed solutions that follow in this paper is to draw attention to changes in our engineering pedagogy that have occurred over the last few years and to encourage a re-focus that may positively affect our undergraduate engineering education. This paper describes some changes in aerospace engineering that have both positive contributions and negative consequences. There are also similar examples and solutions in every other engineering disciplines. Students learn and retain much better when the basics are understood before advanced concepts are introduced, and when practical applications reinforce technical concepts. In the following text, examples of problems created in aerospace engineering are illustrated and some solutions offered. Also, a three course sequence of aerospace engineering courses stressing practical, team-based courses is explained.

Aerospace Engineering Evolution Problems and Practical Solutions

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The use of high powered computing has caused a diminished emphasis on understanding the fundamentals. An example is the focus on the power of computational analysis and the de-emphasizing of experimental verification utilizing wind tunnels. When the computer explosion occurred over 30 years ago, the computational capability was assumed to be so powerful that code verification from other sources was unnecessary and a devastation our wind tunnel facilities began. Many NASA, military, and private wind tunnel facilities were shut down and dismantled because the assumed computational fluid dynamics (CFD) capabilities made these physical facilities seem obsolete. It took many years to finally realize other sources of verification were still necessary to reduce the risk of making a bad decision based on one source of information. It is also documented in recognized reference texts like *Theory of Wing Sections*[1] that the accuracy of theoretical predictions was not nearly as great as anticipated. In fact, the 80 to 90 percent solution using theoretical techniques was extremely optimistic. Because of limitations on theoretical analysis, wind tunnel facilities are currently re-opening and in some cases building new facilities for experimental testing and verification. Many industry organizations (nearly every week a request goes out asking about wind tunnel time for industry applications) are now seeking testing facilities to verify theoretical results. Often, engineering faculty have led the students to believe the theoretical solution is the only valid method when others are available and are actually essential to process the best solution. Sometimes, the students are instructed to use codes they do not understand simply because the faculty member uses these codes in their research. Ultimately, the student learning and motivation goes down. To attain the best solution to a design or modification problem, all available verification methods must be employed. Therefore, a combined method of practically applied basic principles, theoretical predictions, experimental verification, and flight testing will result in the most effective solution.

Another example of ignoring the basics for the theoretical is illustrated by the course curriculum. The computer explosion emphasized theoretical concepts and most curriculum developers added these techniques while maintaining the existing practical courses. When apparently there was not sufficient time for both approaches, the computer-driven theoretical approach prevailed in most university curricula at the expense of the once popular practical approach. One of the authors of this paper was teaching the Aerodynamics I course from a practical text used at two exclusively undergraduate institutions, Embry-Riddle Aeronautical University (ERAU) and the United States Air Force Academy (USAFA). Some faculty who advocate the undergraduate institutions be exactly like the research and publish graduate schools, supported changing to an essentually theoretical, potential flow theory text. The instructor complied and used both texts which effectively nearly doubled the student workload. The increased workload actually decreased some learning objectives but stimulated interest and motivation with the students. However, the author saw other instructors of the course succumb to the pressure to implement the theoretical text and approach to education in aerodynamics. A few semesters later, this author had some of the students from the entirely theoretical aerodynamics course in the capstone design course. It was apparent early in the capstone course the students did not possess the practical knowledge of aerodynamics to be successful in the performance-driven, aircraft design course. The author implemented practical aerodynamics and aircraft performance in the design course to fill the gaps in student understanding created by the purely theoretical approach

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to aerodynamics. This lack of practical knowledge stimulated the author to develop a prerequisite course in aircraft flight mechanics and performance to aide student success in aircraft design. Now the capstone aircraft design courses have been modified to accommodate practical design and wind tunnel testing methodology to develop the best solution.

In the first new course mentioned above (Aircraft Flight Mechanics and Performance), lecture and research techniques are utilized in aerodynamics, aircraft performance, and static aircraft stability to analyze the performance characteristics of a student-selected, existing aircraft. The course lectures contain references from many authors/texts for researching and understanding various techniques to analyze aircraft characteristics. Students apply the various techniques in groups of three in the five assigned projects. The projects also enhance communication skills by requiring five written reports and a final presentation. An outstanding motivational aspect of the course is the students compare results to published results of existing aircraft. In the second course (Aircraft Preliminary Design), student groups of 6 to 9 (Integrated Product Teams, IPTs) are given only performance parameters for a given type of aircraft and the IPT completely designs the prototype, capstone-course aircraft. Results are documented in four presentations and three reports. The final presentation is evaluated by a panel of industry experts who assign a grade for the students and valuable industry perspectives for the students and faculty. In the third course (Aircraft Detail Design), the same design groups continue the capstone experience by taking their aircraft into the next phase of the Research, Development, Test, and Evaluation (RDT&E) process by applying wind tunnel testing, model modification, and re-testing to verify the best design solution. The IPT will complete the project by making a configuration recommendation for the first flight test aircraft to the panel of industry experts. Assessment of the value of this basic knowledge, research, and problem solution technique is measured by the panel of industry representatives who evaluate the final presentations. These documented evaluations show improvement in student success, knowledge retention, and preparation for the freshman engineering job.

The dramatic increase in computational capability (higher speeds, higher densities, better codes, better interfaces, etc.) that started in the 1960s and 1970s spurred a revolution in computational methods. Despite the vast improvements in engineering capability that evolved from this revolution, engineers have failed to solve some basic pedagogical challenges in engineering education caused by this revolution. Several crucial battles have already been lost, and some of the trends may be irreversible. One issue is regarding the topical content and quantity of content in an engineering degree program. Apart from the extra training in math and computer programming required for teaching computational methods, a whole new discipline of grid-making (or meshing) came into being. Furthermore, classical engineering principles had to be extended to computational methods. This was easily more than a year's worth of extra content being added to an already rigorous and challenging degree program. Engineering educators were concerned that our most talented and promising students might opt for the less-demanding 4-year programs in other disciplines. Instead of devising a rational length for the engineering program, this additional material was simply inserted into a four-year, grueling, mind-numbing experience. Then unmanageable programs began systematically cutting out the classical / practical / applied material to make room for the computational addition. A solution to the sometimes over-

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demanding, short engineering program is to maintain the classical approach, introduce some computational theory in the undergraduate curriculum, move some of the computational to graduate curricula, and offer an extended program which could provide depth in some areas of interest to the students.

Another area of concern in aerospace engineering is in an identity crisis. Some engineering programs are deliberately evolving away from ***engineering*** programs toward ***engineering sciences*** programs and in some cases, the transition is virtually compete. The former programs prepare undergraduates to get entry-level jobs as engineers in careers in government or industry. The latter programs screen students to serve initially as low-paid workers in funded research programs and then eventually to earn doctorates for careers in research in academia. As a result, engineering programs have gradually been re-populated with research Ph.Ds. instead of journeymen engineers, and the apprenticeship model of teaching engineering has been replaced with a pedagogical model. We hire and reward professors for writing research grants rather than for stimulating innovation in the students or creating collaboration with engineering activity in industry. Due to lack of experience in industry, what is taught in the curriculum is often not placed into the context of the engineering risk reduction process. Consider how many of the great aircraft designers of the past century -- American or otherwise -- had a Ph.D. The answer, of course, is none. How many of these, regardless of their success in industry, could get a job teaching aircraft design at a “research university” in America today? The answer is, again, none. They don’t have the publications or funded research programs to even get an interview. Many times students ask the faculty what does it take to be successful in the industry environment and the faculty have no reply because there is no experience. The most obvious solution to this problem is more diversity in hiring faculty. Certainly there is a need for credentials in an engineering curriculum, but there is also a need to help guide the students by educating them in the environment they will face upon graduation.

Another concern in aerospace engineering is the engineering co-op program, which provides entry-level experience in industry and partially replicates the classical apprenticeship model of engineering education. Many research professors who want to reduce the number of courses they teach or the number of exams they have to grade are seeking more depth rather than breadth for their students. Even though the apprenticeship model helped produce the generations of American engineers who put men on the moon and created vehicles that fly at hypersonic speeds, research professors in general have no interest in sustaining a co-op program and are usually content to let it decline. Our industry is encouraging co-op experiences to the extent one major company has indicated that in the next five years, no student will be hired from an engineering undergraduate program without co-op experience. So, undergraduate programs must emphasis co-op programs and find innovative ways to schedule these into the curriculum.

A final concern for the aerospace engineering curriculum involves appearances of misuse of the undergrad capstone aircraft design course. Engineers know capstone is essential preparation for that first job in the real world, since it may be one of the few opportunities, if not the only opportunity, an undergrad will have to integrate what they’ve learned in their coursework in the context of the whole system and to realistically exercise multi-disciplinary synthesis, leadership

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and teamwork on large projects. In many cases, however, the capstone aircraft design course has become a dumping ground for requirements not met in other courses. In other cases, students have not been given adequate skills. These skills must then be taught in the design course in some kind of crash-course, lick-and-a-promise fashion that is neither sufficient nor efficient. Time supposedly spent integrating and exercising skills supposedly learned in previous courses is instead spent introducing new skills, which in turn takes away from time required to replicate the iterative nature of the design process. It also significantly drives up the workload in the course, which diminishes the enthusiasm and participation in what should be the most fun course in the entire curriculum. Researchers also see no place in the curriculum for the capstone engineering design course, which functions as an exercise in engineering creativity, engineering risk reduction, and integration of a broad range of engineering sub-disciplines and skills. Engineering design is also conducted at higher technology readiness levels than those seen in research. In many researchers' minds, the time would be better spent enhancing depth of content in a sub-discipline as preparation for graduate research. If it weren't for the professional engineering societies and the agencies that accredit college degrees, the design courses might also have gone the way of the co-op program. Nonetheless, even those who aspire to get a Ph.D. and do research need to understand engineering design and the whole airplane (or other system) as the context for their research. The demand for properly-engineered products is what drives the demand for research. If you don't understand how your research makes the airplane or other system more economically or operationally effective, you can't know if your research is doing any real good and you won't be able to effectively justify your requests for funding. Many researchers would also benefit from the reality check provided by a job out in the real world. A solution may be, as before, the diversity of hiring faculty. Hire some who have the credentials and desire to accomplish research and hire some who have the experience to help prepare the students to be successful in the industry they have chosen.

Summary and Recommendations

The aerospace engineering industry has, over the last few years, emphasized basic, practical engineering education. The co-op programs have increased and hiring from these programs has doubled if not tripled. All of our Industrial Advisory Board members and other industry representatives have complemented the practical, project based education in our curriculum. It is evidenced in the hiring rates for our graduates in the first year after graduation. Although we have no data from other schools, we are told our percentages of graduates who are working in the aerospace profession in their first year after graduation is very high due to our focus on undergraduate education and the graduate's practical application skills.

Ignoring some of the challenges listed in this document and taking the easy way out only guarantees the law of unintended consequences would be enforced with devastating effect. Inserting five years of content into a four year program only served to aggravate the attrition out of engineering and into other, less-demanding degree programs. The fear that we'd lose our talent was fully justified by trends in declining enrollments in engineering. The same justification was also used to get rid of the highly-successful co-op programs, which was an attempt to recover some of the features of the apprenticeship model of teaching engineering. Our

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students now lack intuition that comes from the classical / practical / applied material, and they have no intuitive basis to evaluate what comes out of the computational techniques.
The computational pioneers eagerly over-sold their capabilities, and decision-makers were ready to believe promises about wind tunnels being obsolete and ready to be replaced by cheaper computational methods. Lacking understanding of the limitations of computational methods, having oversold the capability of those methods, and having failed to understand the place of classical / theoretical methods, computational methods, and experimental methods in a multi-phase engineering risk reduction process, we've allowed our experimental capability to atrophy. Wind tunnel capability has eroded to the point that it may not be recoverable. And, we must insist that computational methods be validated against experimental results before they're employed to extrapolate results for new designs.

Some may argue that the ideal is to strike a balance between graduate research in engineering science and undergraduate engineering. A similar argument is that research enhances undergraduate education. Both are true to some extent, but the reality is that graduate research programs tend to grow and absorb disproportionate fractions of funding and faculty attention while undergraduate programs atrophy unless the engineering school deliberately maintains its identity as an engineering program rather than an engineering sciences program.

There are some questions the engineering education community should be asking over the next few years:

1. Do we have the desire to regain our identity and serve our industry customer?
2. Who are we? Scientists or engineers? Graduate programs or undergraduate? What's our first priority?
3. Can we properly structure a curriculum and a faculty and an academic environment that makes sense for undergrad engineering students and the rookie engineers they're about to become?
4. Can we recruit and motivate and incentivize the right students? Can we fix the pipeline?
5. Can we teach the engineering profession or do we just teach technical topics?

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A Proposed Grand Challenges Scholars Program in the Lyles College of Engineering

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Abstract

There has been a growing concern regarding traditional engineering education - for not adequately preparing future graduates who will be able to address society's increasingly complex problems. Future engineers will need a new set of skills in the context of the global economy. Additionally, the retention of engineering students, especially underrepresented students, is another cause for concern. Approximately, 50% of students majoring in engineering graduate within six years. This challenge intensifies considering that fewer incoming students, specifically underrepresented ones, are attracted to the field of engineering and construction management.

The National Academy of Engineering's (NAE) Grand Challenges Scholars Program (GCSP) intends to address the preceding concerns. It will provide the framework for educating the future engineers and construction managers who will be equipped with the necessary skills to solve the Grand Challenges of the 21st century. In 2008, NAE identified fourteen Grand Challenges for the 21st century to highlight the areas of engineering that will have great potential to improve mankind's quality of life. The overarching thematic areas include energy and environment, health, security, and learning and computation. The GCSP has five components: (1) interdisciplinary curriculum, (2) hands-on projects or research experience, (3) entrepreneurship, (4) service learning, and (5) global perspective. The aforementioned roadmap will not only enhance students' skills and knowledge needed to solve complex societal problems, but will provide realistic and exciting opportunities for students to get engaged.

There is an increasing number of engineering programs worldwide adopting the GCSP roadmap within their existing undergraduate and/or graduate education. The details of a proposed GCSP in the Lyles College of Engineering at California State University, Fresno will be discussed in this paper.

Keywords: Grand Challenges, interdisciplinary, entrepreneurship, energy, environment, security

Introduction

There has been much debate concerning the shortcomings of the conventional engineering education in recent years[1, 2]. The culmination of these deliberations has resulted into several landmark publications including: The Engineer of 2020[3], Educating the Engineer of 2020[4], Changing the Conversation[5], Grand Challenges for Engineering[6], Raising the Bar: America's Challenge to Higher Education[7], and The Vision for Civil Engineering in 2025[8].

In the Engineer of 2020 (3), the National Academy of Engineering (NAE) poses an important question: "*Does it serve the nation well to permit the engineering profession and engineering education to lag technology and society? Rather, should the engineering profession anticipate needed advances and prepare for a future where it will provide more benefit to humankind? Likewise, should engineering education evolve to do the same?*" In response, the NAE makes a number of recommendations in the Educating the Engineer of 2020 (4). Accordingly, the characteristics of a successful future engineer will entail: "*strong analytical skills, practical ingenuity, creativity, good communication skills, business and management knowledge, leadership, high ethical standards, professionalism, dynamism, agility, resilience, flexibility, and the pursuit of lifelong learning.*"

Furthermore, in 2008, the NAE identified fourteen global challenges for the 21st century. Grand Challenges are key initiatives fostering innovations to solve the world's problems in relation to sustainability, health, vulnerability, and human wellbeing. Subsequently, in 2009, the NAE Grand Challenges Scholars Program (GCSP) was announced at the GC Summit in Durham, North Carolina[9, 10]. The intent of the GCSP is to prepare students via a combination of curricular and extra-curricular activities so that future engineering graduates will be able to tackle the 21st century grand challenges.

Initially, only a handful of universities adopted the GCSP. Over the years, a growing number of universities worldwide have been incorporating the GCSP in their undergraduate/graduate education in different ways[11-14]. Recently, the Lyles College of Engineering (LCOE) at California State University, Fresno ('Fresno State') has submitted a preliminary proposal to join the GCSP Community. At this time, the LCOE's proposal focuses on the Construction Management (CM) program as a pilot. It is envisioned that the proposal will expand to encompass the remaining five LCOE engineering programs in the future. Following is the outline of the CM's proposed Grand Challenges Scholars Program.

Overview

The undergraduate curriculum for the Construction Management program in the Lyles College of Engineering at Fresno State was overhauled nearly three years ago. The unique features of the revised curriculum comprised an interdisciplinary approach with a business minor as an integral element of the CM major. Service learning was incorporated at all levels in the form of "S" designated courses. At the freshman level, CM 1S, the orientation course; in the mid-level, CM 7S, the construction materials and assembly course; and at the senior level, the capstone course, CM 180S provide the experiential learning opportunities with one or more community based organizations (CBOs) in the field of construction. Each student is obliged to spend a minimum of 20 hours community service learning in construction related jobs as part of the requirement for the an individual "S" designated course, thus, a total of 60 hours by the time of graduation. Furthermore, an internship became compulsory for students enrolled in the new curriculum. Students are required to work in the construction industry for minimum 600 hours to fulfill the internship requirement. A hallmark of the new curriculum is the entrepreneurship component, implemented via seminar series, capstone sequence of courses, and extra-curricular activities.

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It is evident from the preceding brief overview that several elements of the GCSP are embedded within the existing CM's undergraduate education. It is the guiding principle of the proposed initiative to further reform the curriculum and incorporate additional extra-curricular activities, as needed, to realign the CM education in the Lyles College of Engineering at Fresno State with the NAE's Grand Challenges Scholar Program. Following is our vision for developing and incorporating the proposed GCSP roadmap.

Interdisciplinary Curriculum

The NAE's recommendation is to complement the engineering/construction fundamentals with non-engineering/construction courses from other fields to provide a breadth of knowledge in communication, public policy, business, law, ethics, human behavior, risk, and the arts, as well as health care/sciences. The CM curriculum at Fresno State entails a high rigor including calculus courses, a course in statistics, a calculus-based physics course, earth sciences, and all the construction management/science courses required by the accreditation board, the American Council for Construction Education (ACCE). The curriculum is complemented with the required series of courses for a business minor. Furthermore, the curriculum is enriched with variety of courses in communication, public policy, ethics, law, etc., as part of the general education requirement. There are also opportunities available for students to select other minors, certificates, and additional pre-requisite business courses to become "MBA-ready."

Furthermore, it is well known that non-engineering/construction courses are taught in colleges/programs outside the college of engineering. As a result, students see little or no relevance between non-engineering/construction courses and their major field of study. As a part of our proposed GCSP curriculum innovation, we intend to establish a closer partnership with non-engineering/construction programs to bridge these disconnections. One such example is the first author's experience in seamlessly integrating the geology and geotechnical engineering courses via a project-based learning (PBL). Moreover, there will need to be more discussions and presentations introduced at different levels within the program to highlight the Grand Challenges projects. In the past, our case studies in construction failure, incorporated in various courses, have provided broad perspectives of the global infrastructural challenge. We intend to expand the case studies application in other areas of grand challenges in the future.

Hands-On Projects or Research Experience

Multiple courses taught in CM are project-based, especially the capstone series. The selected projects have been at small scale, yet present real world challenges and sharpen students' problem solving skills, which are critical, as they take on greater scale projects in their future career. To enrich students' experiential learning, the CM faculty design these projects with built-in research components such as building performance analysis, sustainability design strategies, lean concepts, etc.

Entrepreneurship

In relation to the entrepreneurship component of the GCSP, the NAE (7) suggests that students should be prepared to translate invention to innovation and "to develop market ventures that

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scale to global solutions in the public interest." As mentioned previously, entrepreneurship constitutes a hallmark of the CM program in the Lyles College of Engineering. Two of the faculty members serve as the Coleman Fellows for Entrepreneurship and are actively involved with the Lyles Center for Innovation and Entrepreneurship. The CM program has been offering courses in relation to entrepreneurship as technical electives as well as a joint certificate program in entrepreneurial real estate in collaboration with the Craig School of Business-Gazarian Real Estate Center. In the past, CM students were exposed to the entrepreneurial activities via seminar and speaker series and by taking relevant courses. They will be engaged at a larger scale dealing with grand challenges as part of the proposed GCSP in the future.

Service Learning

In addition to the required "S" designated courses that provide opportunities for CM students to become engaged in community service activities in construction, we have introduced an award-winning Eco-Village project, in collaboration with a local architect, as an integral part of the senior level capstone courses. A global phenomenon, the Eco-Village movement promotes humane housing, a green and sustainable solution to homelessness. Originally, spearheaded by Mr. Art Dyson, a world-renowned architect, the Eco-Village Project of Fresno will provide safe, sanitary, uplifting and dignified housing for the homeless people locally and emergency shelter for disaster stricken communities globally. Furthermore, the Eco-Village Project is an environmentally sustainable community that provides a holistic safe haven that "gives the mental, emotional and physical tools necessary to escape the endless cycle of homelessness[15]." A multi-disciplinary project, CM students have taken the lead in the past to collaboratively design and build the Eco-Village sustainable modular units. Other members of the team represent interior design, real estate, anthropology, planning, and engineering. Our vision is to scale up the Eco-Village project to the global level for emergency shelter applications.

Global Perspective

The NAE states that the global dimension component of the GCSP should develop and deepen "students' social consciousness and their motivation to bring their technical expertise to bear on societal problems through mentored experiential learning with real clients." The preceding Eco-Village Project, once implemented as emergency shelters globally, will provide an excellent experiential learning opportunity. CM students have also been involved in Engineers Without Borders projects in the past. We envision that students in the GCSP may be able to fulfill their internship requirements working for construction companies overseas, as prescribed in the above statement by the NAE. Moreover, we are in the process of developing study abroad programs, which will provide ample opportunities for students to immerse in another culture and gain global perspective.

Conclusions

The vision of the NAE's GCSP is to advocate a new engineering education paradigm that will prepare engineers who will be "world changers." The proposed GCSP in the Construction Management Program at Fresno State, a pilot program in the Lyles College of Engineering, already possesses several features of the GCSP's five components. The CM education in LCOE,

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realigned with the GCSP's vision, will move to a global context and will provide tremendous opportunities for students to collaboratively solve global grand challenges.

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Expanding the Community College Engineering Educational Pipeline through Collaborative Partnerships

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Abstract

The 2012 President's Council of Advisors on Science and Technology (PCAST) report, "*Engage to Excel*" indicates that the United States needs to produce one million additional STEM professionals in the next decade in order to retain its historical preeminence in science and technology. The report proposes that addressing the retention problem in the first two years of college is the most promising and cost-effective strategy to address this need. The California Community College System, with its 112 community colleges enrolling approximately 2.5 million students—representing nearly a third of the nation's community college student population—is in a prime position to grow the future STEM workforce. However, for most community college engineering programs, developing strategies to increase the number and diversity of students successfully pursuing careers in engineering is a big challenge due to shrinking resources and continuing budget crises.

This paper is a description of how a small Hispanic-serving community college in the San Francisco Bay Area developed effective partnerships with other institutions of higher education and industry partners in order to create opportunities for underrepresented community college students to excel in engineering. These partnerships led to programs that have increased the interest, entry, retention and success in engineering fields among minority students. Among these programs are: a) a summer engineering institute – a two-week residential summer camp for sophomore and junior high school students; b) a ten-week summer research internship program for community college engineering students; c) a two-day summer engineering teaching institute that assists community college engineering faculty in developing technology-enhanced instruction using tablet computers and distance education; and d) alignment of engineering curriculum and development a joint engineering program among participating community colleges. These programs have resulted in strengthening the community college engineering education pipeline in the state.

1. Introduction

Despite increasingly urgent calls to broaden the participation of underrepresented minorities (URMs include African Americans, Alaska Natives, American Indians, Latinos, Native Hawaiians and Pacific Islanders) in engineering not much progress has been achieved. Since 2000, underrepresented minorities' shares in engineering and the physical sciences have been flat despite a rapid increase in their representation of the overall US population. In fact, even though

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underrepresented minorities currently constitute 30 percent of the US population, they account for only about 12.5% bachelor's degrees awarded in engineering.[1]

Community colleges play an increasingly important role in educating students from underrepresented groups. Almost three-fourths of all Latino students and two-thirds of all African-American students who go on to higher education begin their postsecondary education in a community college.[2] However, for many of these students, the community college gateway does not lead to success. Only one in four students wanting to transfer or earn a degree/certificate did so within six years, according to a recent study of California community colleges. African American and Hispanic students have even lower rates of completion. According to the study, only 14% of African American students and 20% of Latino students completed a degree or certificate within six years, compared to 29% of white students, and 24% of Asian students.[3]

The 2012 Council of Advisors on Science and Technology (PCAST) report "*Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*" indicated that addressing the retention problem in the first two years of college is the most promising and cost-effective strategy to produce the STEM professionals needed in order to retain US historical preeminence in science and technology. [4] The California Community College System, with its 112 community colleges and 71-off campus centers enrolling approximately 2.5 million students is in a prime position to grow the future STEM workforce.[5] Unfortunately, most California community college engineering programs are a one-person department with limited resources to address this very important need of broadening participation in the profession among URMs. In fact, many small-to-medium community college engineering programs struggle to offer all the lower-division courses needed by students to be competitive for transfer.[6]

This paper is a description of how Cañada College, a small Hispanic-serving community college in the San Francisco Bay Area, developed effective partnerships with other institutions of higher education to create opportunities for underrepresented community college students to excel in engineering. These partnerships led to programs that have increased the interest, entry, retention and success in engineering fields among minority students. Among these programs are: the summer engineering institute – a two-week residential summer camp for sophomore and junior high school students; a ten-week summer research internship program for community college engineering students; a two-day summer engineering teaching institute that assists community college engineering faculty in developing technology-enhanced instruction using tablet computers and distance education; and alignment of engineering curriculum and development a joint engineering program among partner community colleges. The summer engineering institute and the summer research internship program were developed in collaboration with San Francisco State University School of Engineering, while the summer engineering teaching institute and the joint engineering program were developed in collaboration with Los Angeles Pierce College.

2. **Summer Engineering Institute**

In 2008, Cañada College was awarded a Minority Science and Engineering Improvement Program (MSEIP) grant by the US Department of Education to develop a project that aims to maximize the likelihood of success among underrepresented and educationally disadvantaged

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students interested in pursuing careers in STEM fields by incorporating strategies that address challenges and barriers to recruitment, retention and success of these students. Among the strategies developed for this project is a summer engineering camp developed collaboratively with San Francisco State University (SFSU), a large comprehensive urban university in San Francisco. The Summer Engineering Institute (SEI) is a two-week residential program held on campus at SFSU. The goals of the program are to introduce students to the engineering educational system and the engineering profession, to recruit students into an engineering field, to increase student awareness of resources and skills needed for college success, and to increase student knowledge of specific engineering topics, as well as enhance student self-efficacy in pursuing an engineering career. The first year of implementation of SEI was done through a collaboration with the California Department of Transportation (Caltrans), with the curriculum adopted from Caltrans' engineering institute. This curriculum focused mostly on engineering fields that are relevant to Caltrans missions, and did not provide students the opportunity to explore the many different pathways to the various engineering career options.

In 2010, the SEI curriculum was drastically revised in order to present a more balanced curriculum that introduces participants to the major areas of engineering. This revised SEI curriculum—jointly developed and taught by community college and university engineering faculty—features lectures, hands-on workshops, demonstrations, panels, field trips, team-building activities, social events, and group projects. The curriculum introduces students to the engineering education system in California, as well as details on alternative paths to an engineering career including concurrent enrollment in high school, community college engineering transfer programs, and state universities, as well as private and independent institutions. Most mornings are devoted to lectures and presentations, with group activities and hands-on workshops in the afternoon to reinforce concepts learned from the lectures. Some afternoons are devoted to field trips (e.g., Bay Bridge construction, SF Exploratorium, Academy of Sciences, NASA Ames Research Center) , and most evenings to working on group projects.

SEI Group Projects: One of the most effective factors in enhancing self-efficacy among students is through mastery experiences.[7] To provide those experiences to SEI participants, four culminating group projects corresponding to each of the four main areas of engineering (civil, computer, electrical, and mechanical) were designed. Each student selects two of the four projects based on their initial interests. The first week is devoted to completing the first group project, and the second week is for the second project, with group presentations on the last day of the institute. Project group size varies from 3 students to 6 students depending on student interest and the complexity of the project. Groupings for the first and second projects are different, and are based primarily on student interest as expressed on the opening day of the institute. Groups working on the same project are supervised during project time by either a graduate student, or an upper-division SFSU student who acts as the project mentor. Each project mentor works closely with SFSU faculty in designing the project and planning daily activities. The computer engineering project involves the design and creation an iPhone App that has an academic application (e.g., unit conversion, math formulas). The Civil Engineering project involves the use of computer applications and simulations to design a truss bridge and build a model of the bridge using available materials in the PASCO Scientific kit (http://www.pasco.com/). The Electrical Engineering group project uses the BASIC Stamp Activity Kit from Parallax, Inc. (http://www.parallax.com/) to design, build and test simple circuits, and understand the basics of

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microcontrollers, computer hardware and programming. The Mechanical Engineering project uses an off-the-shelf Stirling engine kit to understand the fundamentals of heat engines, thermodynamic processes, and energy conversion efficiencies. For all of these projects, students prepare a report and an oral presentation of their results. Oral presentations in front of faculty, professional engineers, and parents are done at the last day of the institute.

Other SEI Workshops: In addition to the above culminating projects, SEI also offers a variety of other workshops related to academic, personal, and professional development. One such workshop provides participants with an overview of renewable energy. Using the Invicta Plastics Renewable Energy kits (http://www.fisher.co.uk/), students learn about the various forms of renewable energy (solar, wind and hydro power), how these forms of energy can be converted into useable (mechanical or electrical) energy, and their pros and cons. Additionally, SEI offers workshops on résumé writing, public speaking, and robotics, as well as team-building exercises, panel discussions, and hands-on demonstrations and activities representative of the major fields of engineering.

Profile of SEI Students: In selecting participants for the SEI, the project team has made a conscious effort to give special consideration to minority, female, and first-generation college students, and those from underrepresented minority groups. Table 1 shows a summary of the demographics of students selected to participate in the program. The percentage of students from underrepresented minority groups is 81.9%, with Hispanics constituting the largest ethnic group at 64.5%. The percentage of students who are the first in their families to go to college is 58.1%. More than half of the participants are female students.

Table 1. Demographics of Summer Engineering Institute participants for 2009 to 2014.

Demographics	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**Total**	**%**
Gender								
Female	13	14	15	14	13	13	82	52.9%
Male	12	12	11	12	13	13	73	47.1%
Total	25	26	26	26	26	26	155	
Ethnicity								
African American	3	1	3	3	3	3	16	10.3%
American Indian	0	0	1	1	2	0	4	2.6%
Asian American	5	2	1	4	4	1	17	11.0%
Caucasian	2	3	2	3	5	2	17	11.0%
Hispanic	12	20	18	14	17	19	100	64.5%
Pacific Islander	1	0	1	1	3	1	7	4.5%
Other/Unknown	2	0	0	0	0	0	2	1.3%
Total	25	26	26	26	26	26	155	
First in Family to Attend College?								
Yes	11	14	16	19	13	17	90	58.1%
No	14	12	10	7	13	9	65	41.9%
Total	25	26	26	26	26	26	155	

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SEI Results: Table 2 is a summary of the average student ratings of the usefulness of the projects. From 2010 to 2014, steady improvements of the ratings of the projects are observed over the past four years, with the exception of the 2012 iPhone Project. Yearly increases in student ratings of the project can be attributed to the program improvements made as a result of lessons learned from previous years. For the 2012 iPhone project, the low student average rating is brought about by the combination of technical difficulties (old computers not working properly with the software) and a last-minute switch to a graduate student mentor who does not have a solid background in iPhone Apps. The drop in student average rating of the Sterling Engine project in 2013 may again be attributed to the new student mentor in charge of the project.

Table 2. Student Ratings of the Usefulness of SEI Projects. Response Scale: 5 – A Lot, 4 – Quite a Bit, 3 – Some, 2 – A little, 1 – Not at All Useful.

Projects	2010	2011	2012	2013	2014
Bridge design	4.00	4.33	4.70	4.65	4.90
Designing a Timer	4.27	4.33	4.72	4.36	4.25
iPhone project	4.10	4.65	3.81	4.20	4.23
Sterling Engine kit	4.26	4.60	4.75	4.06	4.60

Student Survey Results: Self-Efficacy: One of the goals of SEI is to improve student self-efficacy in succeeding as an engineering student. To determine the impact of SEI on student self-efficacy, the Baldwin Confidence Survey Form was used in 2014.[8] In this survey, which was created to measure self-efficacy in STEM, participants respond to statements on a five-point scale, ranging from strongly disagree to strongly agree. Statements are phrased both positively and negatively (items 4, 7, 9, and 14 of the survey) to increase reliability and reduce apathetic answers. Table 3 (on the next page) shows a summary of the results of the pre- and post-SEI self-efficacy survey. Among all 15 items in the survey, a statistically significant favorable change in student responses is observed only for item 8. For all the other items, the change is not statistically significant.

When compared to results of other STEM self-efficacy studies using the Baldwin Confidence Survey, the SEI participants have very high self-efficacy based on both the pre- and post-surveys. For instance, the mean responses of SEI students are about one full point more positive than those reported from a survey of 23 engineering and computer science students who were participants of the ACE Scholarship Program at California State University, Fullerton.[9] Because of the initially high levels of self-efficacy among the SEI participants, a significant increase in their self-efficacy is difficult to achieve. Among the possible contributors to high self-efficacy of these students are the SEI selection procedure, which involved a nomination process initiated by a high school math or science instructor. Furthermore, during the SEI Orientation Program, the students and their parents were informed of the highly competitive nature of the SEI selection process, with less than 20% of the applicants being selected. This sense of being one of the few selected to participate in the program may have boosted the participants' initial self-efficacy.

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Table 3. SEI Student Self-Efficacy Survey: Response Scale: 1 – Strongly Agree, 2 – Agree, 3 – Neutral, 4 – Disagree, 5 – Strongly Disagree.

Survey Question	Pre-Program	Post-Program	Change
1. I am confident I have the ability to learn the material taught in Engineering.	1.69	1.65	-0.04
2. I am confident I can do well in Engineering.	1.81	1.85	0.04
3. I think I will do as well or better than other students in Engineering.	2.27	2.12	-0.15
4. I don't think I will be successful in Engineering.	4.09	4.17	0.08
5. I am confident that I can understand the topics taught in Engineering.	1.85	1.81	-0.04
6. I believe that if I exert enough effort, I will be successful in Engineering.	1.31	1.38	0.08
7. I feel like I don't know a lot about Engineering compared to other students.	3.08	3.46	0.38*
8. Compared with other students, I think I have good study skills.	2.35	2.31	-0.04
9. Compared with other students, I don't feel like I'm a good student.	4.12	3.84	-0.28
10. I am confident I can do well on the lecture exams in Engineering.	2.08	2.19	0.12
11. I am confident I can do well in the labs in Engineering.	1.81	1.69	-0.12
12. I am confident I can do well in the projects in Engineering.	1.69	1.42	-0.27
13. I think I will receive a C or better in Engineering courses.	4.22	3.96	-0.26
14. I don't think I will get a good grade in Engineering courses.	2.04	1.73	-0.31
15. I am confident that I could explain something learned in this program to another person.	1.69	1.65	-0.04

* The difference is statistically significant ($p < 0.01$).

Follow-up Survey for 2009-2012 SEI Graduates: A follow up survey was administered to graduates of the Summer Engineering Institute. Only students who participated in the 2009, 2010, 2011 and 2012 are included in the survey since most 2013 and 2014 attendees would still have been in high school at the time of the survey. The purpose of the survey is to determine students' current educational status, the major that they are currently pursuing or are intending to pursue, and whether or not attending the SEI has made any impact in their educational and career goals. The survey notification was sent by email and completed online.

Out of the101 SEI graduates targeted by the survey (25 for 2009, and 26 each for 2010, 2011 and 2012), 55 students responded. This corresponds to a response rate of 54%. Unfortunately, several of the email addresses used are no longer current, and the survey invitation sent by email bounced back. All 55 of the survey respondents are still in school. Out of the 55 respondents, 45 (or 82.5%) are engineering majors, 3 are STEM (non-engineering majors), and 7 non-STEM.

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The percentage of survey respondents who are majoring in engineering (82.5%) compares favorably with the percentage of students who declared one of the engineering fields as their major (76.7%) immediately following the SEI.[10]

The follow-up survey also attempts to determine student attitudes towards SEI and whether or not participation in the program has an impact on the career path they have chosen. Student responses are summarized in Table 4. When asked how much they agree with the statement "I enjoyed participating in the Summer Engineering Institute," the average response is 4.78. The average response for engineering majors (4.78) is slightly lower than those who are non-engineering majors or undecided (4.80). With respect to the prompt "My participation in SEI has a significant impact on my choice of career," the average response is 4.38. Understandably, there is a significant difference in the average response for the engineers (4.47, which is between "Agree" and "Strongly Disagree") and the average response for non-engineers (4.00, "Agree"). As a whole, the SEI is viewed very positively by the students, and has had a significant influence in students' choice of majors, especially those who decided to pursue a major in engineering.

Table 4. SEI Follow-up Survey: Student Attitudes Towards SEI. Response Scale: 5 – Strongly Agree, 4 – Agree, 3 – Neutral, 2 – Disagree, 1 – Strongly Disagree.

Follow-up Survey Prompt	**Engineers (N=45)**	**Non-Engineers (N=10)**	**All (N=55)**
I enjoyed participating in the Summer Engineering Institute.	4.78	4.80	4.78
My participation in SEI has a significant impact on my choice of career.	4.47	4.00	4.38

3. Creating Opportunities for Minorities in Engineering, Technology, and Science

In fall 2010, Cañada College collaborated with San Francisco State University School of Engineering to create the Creating Opportunities for Mathematics, Engineering, Technology, and Science (COMETS) program. Funded by NASA through the Curriculum Improvements Partnership Award for the Integration of Research (CIPAIR) program, the COMETS program was developed to provide opportunities for underrepresented community college students to excel in STEM. Among the strategies developed through COMETS is a ten-week summer research internship program that is specifically designed for freshmen and sophomore community college engineering students.

The ten-week COMETS Summer Research Internship Program has been designed to include full-time positions for students who have completed all lower-division course work, and half-time positions for students who have at least another year in a community college before transfer, in order to allow them to take courses they need for transfer while participating in the internship program. For the 2011 and 2012 COMETS internship programs, three research groups were formed, one in civil engineering, one in computer engineering, and one in electrical engineering. For the 2013 and 2014 internship programs, the mechanical engineering group was added. Each

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group consists of one full-time intern and three to four half-time interns. Each group is mentored by a half-time graduate student under the supervision of a university faculty.

Demographics of Program Participants: Selection of COMETS interns is done through an online application process that takes into consideration student GPA, intended major, STEM courses completed (minimum requirement is completion of the first semester physics course), extracurricular activities, statement of academic and professional goals, statement of research interest, and a recommendation letter from a STEM instructor. Although the primary consideration for assigning students to a particular research group is their declared major, student academic preparation (specifically engineering courses completed) is taken into consideration to ensure that they have the recommended background knowledge needed for the research projects.

Table 5 summarizes the demographics of the community college students who participated in the COMETS summer research internship program in 2011, 2012, 2013, and 2014. Interns were predominantly male and Hispanic. Efforts have been made to increase participation among female students such that the number of female students in the program increased from two in both 2011 and 2012 to five in 2014. The program has been successful in recruiting underrepresented minorities (African American, Hispanic, and Pacific Islanders); about 80% of participants are from underrepresented minority groups.

Table 5. Demographics of Summer Research Internship Program participants from 2011 to 2014.

Demographics	2011		2012		2013		2014	
	N	(%)	N	(%)	N	(%)	N	(%)
Gender								
Male	10	83.3%	11	84.6%	13	81.2%	11	68.8%
Female	2	16.7%	2	15.4%	3	18.8%	5	31.2%
Total	12		13		16		16	
Ethnicity								
American Indian	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Asian	2	16.7%	0	0.0%	1	6.3%	3	18.8%
Black	0	0.0%	1	7.7%	1	6.3%	2	12.5%
Hispanic	10	75.0%	9	69.2%	11	68.8%	9	56.3%
Pacific Islander	0	0.0%	2	15.4%	1	6.3%	0	0.0%
White	0	8.3%	1	7.7%	2	12.5%	2	12.5%
Total	12		13		16		16	

Assessing the Impact of the COMETS Research Internship Program: In order to assess the impact of the research internship program, pre- and post-program surveys were developed and administered electronically to the participants. Prior to the 2014 internship program, the student surveys used were designed by the COMETS team members. This survey consists of a number of questions designed to measure students' perception of their possession of specific skills related to performing research, designing/performing an experiment, creating a work plan, working as part of a team, writing a technical report, creating a poster presentation, and making an oral presentation. These questions (with a response scale of "1" for "nothing" and "5" for "a lot")

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were given immediately before and immediately after the program. The results of the post-program survey on student perception of skills learned from participating in the program is shown in Table 6. For each of the categories, the average response is between “Quite a bit” and “A lot,” indicating an overall high satisfaction with the program.

Table 6. Summary of student responses to the post-program survey measuring the perceived benefit of participating in the research internship program.

Question: How much did you learn about each topic?	**Average Rating**			
1–Nothing; 2–A little; 3–Some; 4–Quite a bit; 5–A lot.	**2011**	**2012**	**2013**	**2014**
Performing research	4.7	4.8	4.9	4.3
Designing/performing an experiment	4.7	4.9	4.9	4.5
Creating a work plan	4.5	4.8	4.8	4.7
Working as a part of a team	4.8	4.8	4.8	4.6
Writing a technical report	4.5	4.8	4.6	4.5
Creating a poster presentation	4.7	4.7	4.7	4.6
Making an oral presentation	4.7	4.6	4.8	4.5

Additionally, a set of post-program survey questions were asked to measure students’ perception of the usefulness of and satisfaction with the internship program, including whether it has been helpful in preparing them for transfer, solidifying choice of major, increasing likelihood of pursuing graduate school, and increasing likelihood of applying for other internships. The responses were given in a Likert scale, “1” for “strongly disagree” and “5” for “strongly agree.” The pre-program survey was administered at the beginning of the first day of the internship program, following the orientation, and the post-program survey was administered immediately following the student final presentations at the end of the internship program.

Table 7. Summary of student satisfaction with the summer research internship program.

Question: Tell us how much you agree with each statement. 1–Strongly Disagree; 2–Disagree; 3–Neutral; 4–Agree; 5–Strongly Agree.	**Average Rating**			
	2011	**2012**	**2013**	**2014**
The internship program was useful.	4.8	4.9	4.9	4.6
I believe that I have the academic background and skills needed for the project.	4.2	4.1	4.6	4.4
The program has helped me prepare for transfer.	4.3	4.5	4.6	4.2
The program has helped me solidify my choice of major.	4.6	4.3	4.8	4.2
As a result of the program, I am more likely to consider graduate school.	4.7	4.6	4.1	4.0
As a result of the program, I am more likely to apply for other internships.	5.0	4.8	4.9	4.8
I am satisfied with the NASA CIPAIR Internship Program.	4.7	4.8	4.8	4.6
I would recommend this internship program to a friend.	4.8	4.8	4.9	4.8

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Table 7 on the previous page summarizes the results of the post-program student survey for questions designed to measure perception of over-all usefulness of the research internship program in 2011, 2012, 2013, and 2014. Results show that the research internship program was successful in achieving its goals of helping students prepare for transfer, solidify their choice of major, increase their confidence in applying for other internships, and enhance their interest in pursuing graduate degrees. Overall, students were satisfied with the program, and would recommend it to a friend.

4. Summer Engineering Teaching Institute and Joint Engineering Program

For years, the 2+2 concept, wherein students are able to complete all of their lower-division coursework at a community college and then transfer to a four-year institution to complete a bachelor's degree, worked well for community college engineering students in California. For instance, in 2002, the California Council on Science and Technology reported that 48 percent of graduates with engineering degrees from the California State University (CSU) and University of California (UC) systems began at community colleges and then transferred.[11] This was made possible by a common set of lower-division courses—commonly referred to as "the engineering core"—required by four-year engineering programs and replicated at community colleges. Students were able to start their engineering coursework and complete the lower-division requirements at a local community college with the option of transferring to one of the many four-year schools across the state.

Recently, the diversification of transfer requirements among university engineering programs has led to the erosion of the core, and has increased the number of courses that community colleges must offer in order to maintain transfer options to different engineering majors and different universities. The diversification includes variability of requirements for students in the same major transferring to different institutions, as well as for students in different majors transferring to the same university, and has resulted in declining enrollments in community college engineering programs.[12]

In response to this pressing need to strengthen community college engineering programs, Cañada College collaborated with Los Angeles Pierce College to develop two programs to help strengthen California community college engineering programs: the Summer Engineering Teaching Institute (SETI) and the Joint Engineering Program (JEP). The SETI is a the two-day institute that helps community college engineering faculty develop to improve teaching and increase the number of students completing required lower-division courses through online delivery. It includes workshops on the following topics: using Tablets for class lectures, video capture and sharing, classroom formative assessment, developing a technology-enabled interactive classroom, flipping the classroom, synchronous online and face-to-face delivery, and developing online labs. Two separate two-day SETI sessions are held every summer: one at Cañada College in Redwood City for institutions in Northern California, and one at Los Angeles Pierce College for institutions in Southern California.

Since 2011 over 100 community college engineering, math, and physics instructors from over 50 California community colleges have participated in the SETI. Surveys of SETI participants

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indicate a high satisfaction rate with the program. These surveys also identified that some of the most commonly perceived potential barriers for the adoption of promising teaching practices include the lack of time required to adapt and implement these practices in the classroom, the cost to implement them, and lack of support from colleagues.

The main goal of the Joint Engineering Program (JEP) is to better serve engineering students in California community colleges by aligning engineering curriculum at partner institutions and increasing student access to lower-division engineering courses through distance education. Engineering faculty from the JEP partner institutions also work together in developing and sharing teaching resources. This supportive community of educators is important because in most cases these community college engineering faculty are the only full-time engineering instructor at their institution. As of fall 2014, there are 23 active partner institutions in the JEP. The thirteen partner institutions from Northern California are Cañada College, Cabrillo College, College of Marin, College of San Mateo, Cosumnes River College, Las Positas College, Mission College, Monterey Peninsula College, Ohlone College, Sacramento City College, Santa Rosa Junior College, West Valley College, and Yuba College. The ten partner institutions from Southern California are Allan Hancock College, East Los Angeles College, Fullerton College, Los Angeles Pierce College, Los Angeles Southwest College, Los Angeles Trade Technical College, Moorpark College, Pasadena City College, Southwestern College, and Ventura College. The following online courses are offered through the Joint Engineering Program: Statics, Dynamics, Circuits Lecture, Materials Science, MATLAB, and Intro to Programming.

Through JEP, curriculum for engineering courses are aligned with respect to number of units, prerequisites, catalog description, student learning outcomes, and course outline/topics. The JEP has completed aligning curriculum and has developed course descriptors (C-IDs) for 11 lower-division engineering courses, as well as Associates in Science degree and Transfer Model Curriculum (TMC) in three areas: Mechanical/Civil Engineering, Electrical Engineering, and Computer Engineering. These course descriptors and TMCs have served as the starting framework for the statewide Course Identification Numbers (C-IDs) and Transfer Model Curricula required under California Senate Bill 1440.[13] This bill, which establishes the Student Transfer Achievement Reform Act, requires that a student who receives an “associate degree for transfer” be deemed eligible for transfer into a California State University. This bill is intended to streamline the transfer process for community college students. The adoption of common lower-division curriculum will not only simplify the articulation of courses with four-year universities, but will also make it easier for students to transfer earned college credits from one community college to another, or from one four-year institution to another. It will also simplify the articulation process by eliminating the need for course-to-course, institution-to-institution articulation agreements. With over 100 community colleges, 23 CSU campuses, and 10 UC campuses, a statewide articulation system would result in significant savings in time and resources.

The success of the SETI and the JEP in strengthening community college engineering programs is manifested in the significant increases in enrollments in engineering courses at the partner institutions. A survey of enrollments in engineering courses at the JEP partner institutions shows an overall enrollment increase of 39.1% from 2010 to 2014 despite the fact that over the same period, total enrollments at the JEP partner institutions decreased by 7.5%

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5. Future Plans

The collaborative projects described in this paper have made significant contributions to strengthening the engineering education pipeline in California. The Summer Engineering Institute has increased awareness of and interest in engineering careers among high school students, many from underrepresented groups. The COMETS summer research internship program has helped strengthen community college engineering students' commitment to their education and prepare them to transfer to a four-year university as engineering majors. Cañada College and San Francisco State University will continue these collaborative programs through a grant from the US Department of Education through the Hispanic-Serving Institution Science, Technology, Engineering, and Mathematics (HSI STEM) program.

The Summer Engineering Teaching Institute and the Joint Engineering Program have contributed to strengthening California's community college engineering programs by allowing small-to-medium programs to offer more online classes on lower-division engineering courses, many of which would have been canceled due to low enrollment. As a result, the number of community college engineering students who are able to take these courses and be prepared for upper-division courses upon transfer has increased. However, courses requiring laboratory components are currently not offered online at any of the partner colleges. As a result many students are not able to complete the required lab courses before transfer, and programs addressing this need should be developed.

Starting October 2014, Cañada College is collaborating with College of Marin and Monterey Peninsula College to develop and implement the *Creating Alternative Learning Strategies for Transfer Engineering Programs (CALSTEP)*. Funded by three-year grant from the National Science Foundation through the Improving Undergraduate STEM Education (IUSE) program, CALSTEP aims to further strengthen community college engineering programs by developing core engineering laboratory courses that are delivered either completely online, or with limited face-to-face interactions. These laboratory courses, together with the online lecture courses developed through the SETI and the JEP, will enable community college students from colleges with limited engineering course offerings to complete the required lower-division engineering courses needed for transfer. CALSTEP is also developing alternative models of flipped classroom instruction to improve student success and enhance student access to engineering courses that otherwise could not be supported in traditional delivery modes due to low enrollment. The project will also train engineering faculty in effectively using the curriculum, and facilitate the continued improvement of the curriculum through the JEP. This new initiative is expected to further improve access to engineering education among thousands of California community college students, especially those from underrepresented groups, and further strengthen the state's community college engineering educational pipeline.

Acknowledgements

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Engineering Improvement Program (MSEIP, Award No. P120A080080), and the Hispanic-Serving Institution Science, Technology, Engineering, and Mathematics (HSI STEM) Program, Award No. P031C110159.

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Engaging Community College Students in Engineering Research through Design and Implementation of a Cyber-Physical System for Myoelectric-Controlled Robot Car

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Abstract

To improve undergraduate STEM education and increase the recruitment and retention of STEM students, engaging community college students in cutting-edge STEM research is a significant strategy for inspiring students' interest in STEM and enabling them to discover their capacity to use STEM to make a difference in the world. With support from the NASA CIPAIR (Curriculum Improvements and Partnership Award for the Integration of Research) program, in summer 2014, four sophomore engineering students from Cañada College, a Hispanic-Serving community college in California's Silicon Valley participated in a ten-week summer research internship project in a research lab on intelligent cyber-physical systems (CPS) at San Francisco State University, a public comprehensive university. In this project, the four student interns learned concepts of CPS and the corresponding emerging technologies in electrical and computer engineering. Supervised by an engineering faculty advisor and a senior student mentor, the student interns gained hands-on research experience by developing a biomedical CPS for myoelectric-controlled robot car, which allows users to use arm gestures to control a robot car wirelessly. The student researchers learned valuable engineering knowledge and skills in this multidisciplinary project including acquisition and analysis of bioelectrical signals, programming on microcontrollers, embedded system design, wireless communication, and various analog and digital interfaces. In addition, the project provided a great opportunity for the students to improve their skills in teamwork, communication, writing, presentation, project management, and time management. The outcome of this project indicated that the summer research internship program was an effective method for engaging community college students in engineering research and strengthening their confidence and interest in pursuing an engineering profession.

Introduction

There is broad consensus that an adequate supply and quality of workers in the science, technology, engineering, and mathematics (STEM) fields is essential to continued U.S. economic competitiveness and growth. In the STEM education pipeline, community colleges play an increasingly important role in preparing skilled STEM workers as well as students who will continue their education at four-year institutions. The role of community colleges in

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undergraduate education is even more prominent for individuals from groups traditionally underrepresented in STEM fields. To improve undergraduate STEM education and increase the recruitment and retention of STEM students, engaging community college students in cutting-edge STEM research is a significant strategy for inspiring students' interest in STEM and enabling them to discover their capacity to use STEM to make a difference in the world. With support from the NASA CIPAIR (Curriculum Improvements and Partnership Award for the Integration of Research) program, in summer 2014, four sophomore engineering students from Cañada College, a Hispanic-Serving community college in California's Silicon Valley participated in a ten-week summer research internship project on intelligent cyber-physical systems (CPS) in the Intelligent Computing and Embedded Systems Lab (ICE Lab) at San Francisco State University, a public comprehensive university. CPS is an emerging technology that features a tight combination of, and coordination between a system's computational elements and physical elements. It has a wide range of applications in areas such as healthcare, aerospace, automotive, civil infrastructure, transportation, entertainment, consumer appliances, etc. In recent years, CPS has been identified by the National Science Foundation as a key area of research. In this project, the four student interns learned concepts of CPS and the corresponding emerging technologies in electrical and computer engineering. Supervised by an engineering faculty advisor and a senior student mentor, the student interns gained hands-on research experience by developing a biomedical CPS for neural-controlled robot car. The neural signals collected by the developed CPS were Electromyographic (EMG) signals, which are effective bioelectrical signals for expressing movement intent[1] and have been extensively studied for its potential use in many engineering applications, such as assistive devices for rehabilitation[2], myoelectric-controlled prostheses[3], motion-controlled games and apps[4]. This project aimed to provide an environment for the student researchers to learn emerging CPS technologies and valuable research skills in this multidisciplinary project. In addition, the project provided a great opportunity for the students to improve their skills in teamwork, communication, writing, presentation, project management, and time management.

Project Design and Experimental Results

The overall architecture of the designed system is shown in Figure 1. The system consists of two modules: a neural-machine interface (NMI) module, and a motor control module. The NMI module is the key to the success of such biomedical CPSs. It senses EMG signals from the user's arm muscles continuously, interprets the signals to identify the user's arm gestures, and converts the recognized gestures to specific executable commands for controlling the robot car such as start, stop, speed up, slow down, turn left, turn right, etc. The motor control module receives the commands from the NMI module wirelessly using a Bluetooth low energy module and converts the commands into voltage pulse trains to control the rotational speed and direction of the motors of the car wheels.

A. Implementation of the NMI Module

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The NMI module is composed of a TI launchpad featuring an MSP430 microcontroller unit (MCU), two EMG sensors placed on the bicep muscles on the user's two arms (one on each arm), two clipper circuits, a USB battery pack, as well as a Bluetooth Low Energy (BLE) transmitter (Bluegiga BLE112). The EMG sensors are equipped with two filters which both rectify the analog output of the EMG sensors, and also smooth the signal and amplify it. The purpose of the two clipper circuits is to prevent the EMG sensors from outputting too large a signal to the launchpad. The launchpad is only rated for a max input of 3.6 volts; however, the EMG sensors can output a voltage signal with amplitude of one volt less than the voltage of the battery, in this case up to approximately 17 volts. Using a 3-volt Zener diode and a resistor the analog output from the EMG sensors is effectively clipped at three volts, allowing for a much safer circuit. The analog output signals from the clipper circuits are streamed into the MCU and converted into digital information by two analog-to-digital converter (ADC) channels on the MCU. The signals are then interpreted by a special command recognition algorithm, and then the identified commands are transmitted to the motor control module via the BLE transmitter.

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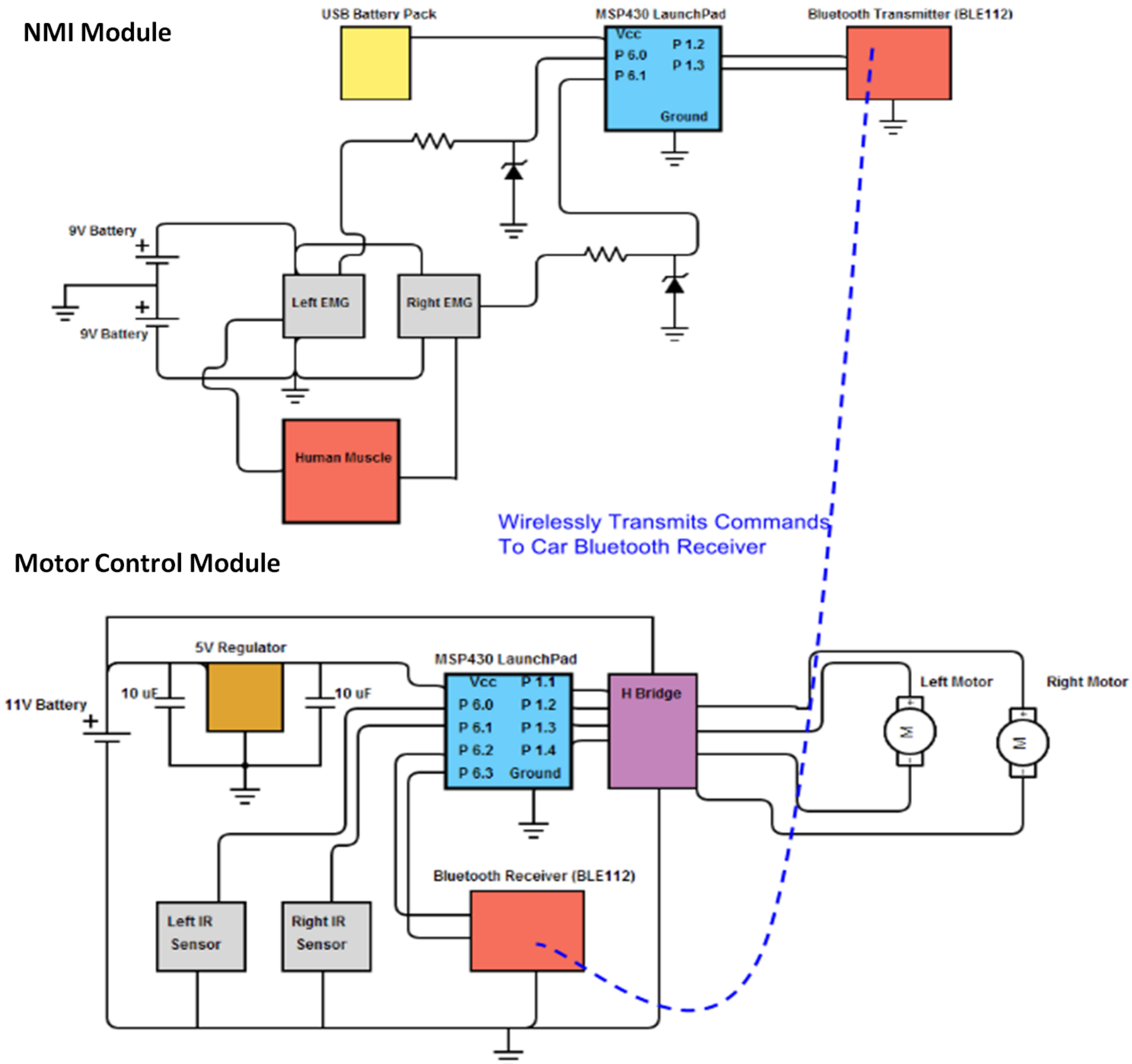

Figure 1. Overall System Architecture

Command Recognition Algorithm: The EMG signals are interpreted in a way by looking at two different possible scenarios, *holds* and *pulses*. A *hold* is defined as a prolonged flex of the muscle being monitored where the signal being interpreted stays above a voltage threshold value for a specific period of time (approx. 1.5 seconds). A *pulse* is defined as a muscle contraction with its duration less than a hold and its resulted signal amplitude above the same threshold. A representative digitally converted signal from an EMG sensor can be seen in Figure 2, which shows the difference between a hold and a pulse, as well as the threshold value. In this design, 7

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commands are defined, including start, stop, speed up, slow down, turn left, turn right, and reverse. Figure 3 shows the flow chart of the command recognition algorithm. When the microcontroller reads two holds (one from each arm), this command starts the car when the car is off, and stops the car when the car is on. When the car is on and the user pulses their right arm this increases the speed of the car, when the left arm is pulsed it decreases the speed of the car. When the car is on and the right arm is held, the car turns right for the duration of the hold, and vice versa when a left hold is performed. Finally we plan on implementing a double pulse command for when the car is not moving forward that will cause the car to go in reverse.

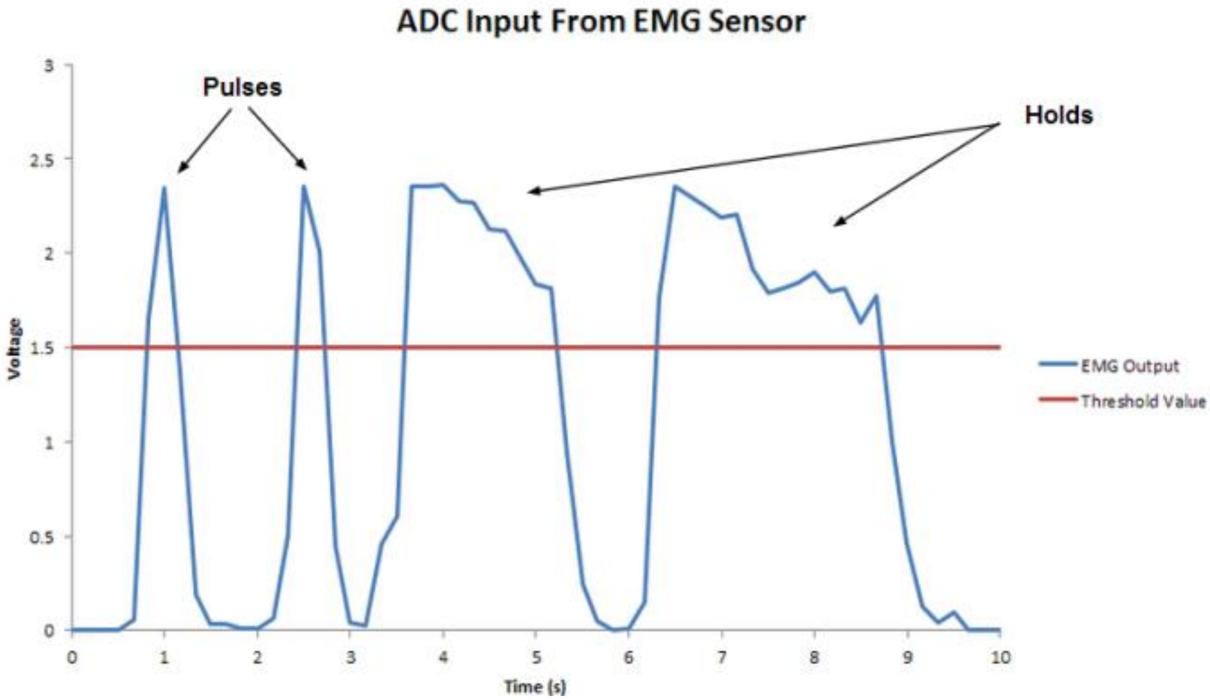

Figure 2. A representative EMG signal showing the difference between a hold and a pulse, as well as the threshold value.

B. Implementation of the Motor Control Module

The motor control module is composed of a TI launchpad featuring an MSP430 MCU, two DC motors (Goldsun Electronics HN-GH12-1640Y-R), two SHARP infrared (IR) sensors, an H-bridge, an 11-volt lithium ion battery and a voltage regulating circuit controlling the voltage powering the launchpad, and a BLE receiver (Bluegiga BLE112). The BLE receiver gets commands from the BLE transmitter on the NMI module. According to the commands, four pulse-width-modulation (PWM) output pins on the MCU are used to generate three possible control signals, i.e. motor forward at specific speed, motor off, or motor in reverse at specific speed. The two IR sensors are mounted on the left and right sides of the front of the vehicle and are used to detect any obstacles. A special *failsafe mechanism* is developed based on both the IR sensor readings and the commands from the NMI module to avoid contact with obstructions. The triggering of the failsafe mechanism is activated when the distance measured by the IR sensors

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from the obstacles reaches a specified threshold. At this time, a finite state machine will take control of the system, disabling any operator usage and will take navigation of the vehicle away from any obstructions.

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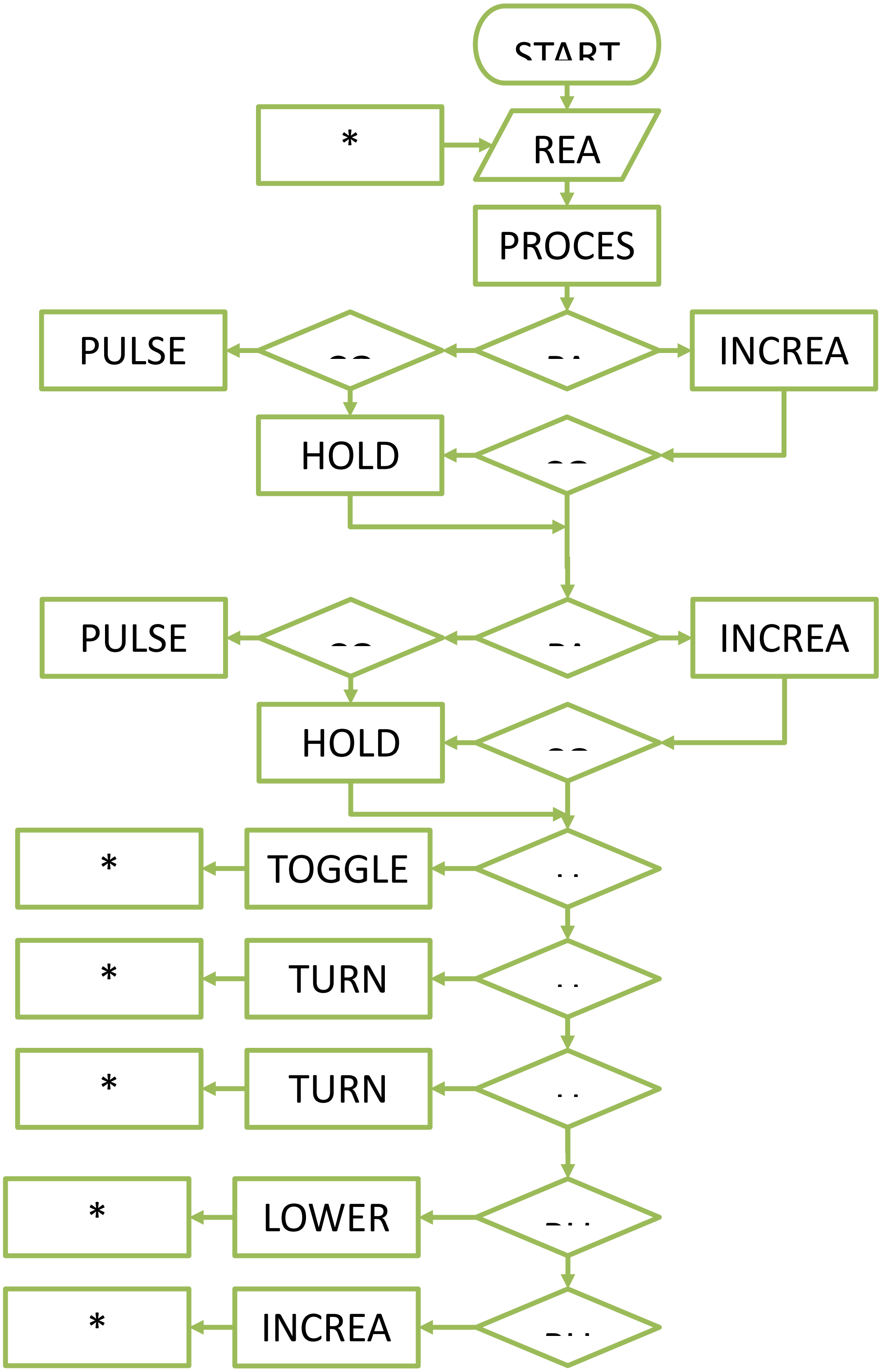

Figure 3. Flowchart of the command recognition algorithm

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C. Experimental Results and Discussion

Real-time testing of the developed myoelectric-controlled robot car was conducted on one male human subject. The experimental setup of the EMG electrode placement and the robot car can be found in Figure 6 and Figure 7, respectively. Each of the commands, i.e. left hold (turn left), right hold (turn right), double hold (start/stop), left pulse (speed up), and right pulse (slow down), was tested 20 times. The recognition accuracy for each command was 90%, 100%, 95%, 100%, and 100%, respectively, which demonstrated the system validity with satisfied accuracies. In the future, the failsafe mechanism will be evaluated and more subjects will be recruited for further validating the system performance. In addition, the adoption of more EMG sensors and more complex signal processing methods such as pattern recognition algorithms will be considered to improve the command recognition algorithm to allow additional control commands such as reverse as well as more accurate control.

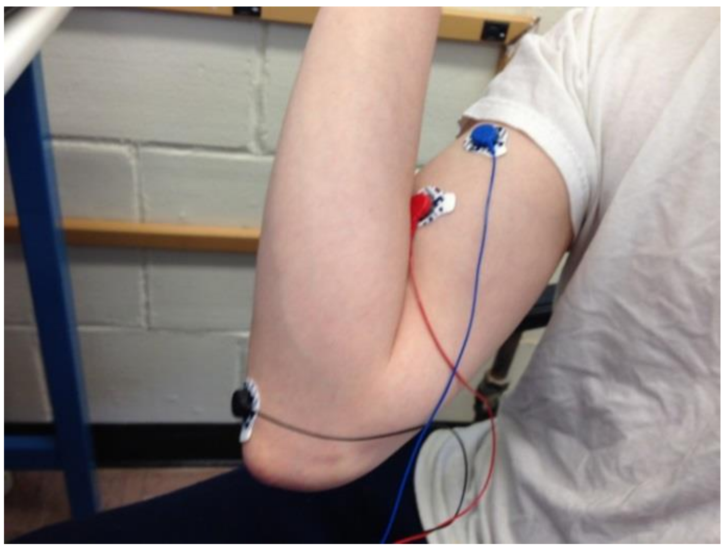

Figure 4. EMG electrode placement on the subject

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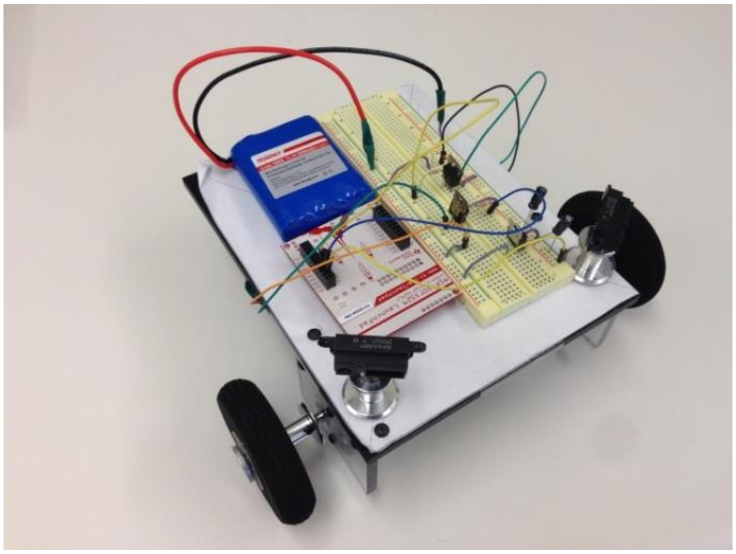

Figure 5. The designed robot car

Project Assessment

A post-program survey was conducted for all sixteen students participating in the CiPair program including another twelve students in the mechanical, computer, and civil engineering. Table 1 summarizes the results of the survey on student perception of skills learned from participating in the program. The results for questions designed to measure perception of over-all usefulness of the research internship program are shown in Table 2.

Table 1. Summary of student responses to the post-program survey measuring the perceived benefit of participating in the research internship program.

Question: As a result of your participation in the program, how much did you learn about each of the following? 1 – Nothing; 2 – A little; 3 – Some; 4 – Quite a bit; 5 – A lot.

Activity	**Average Rating**
Performing research	4.3
Designing/performing an experiment	4.5
Creating a work plan	4.7
Working as a part of a team	4.6
Writing a technical report	4.5
Creating a poster presentation	4.6
Making an oral presentation	4.5

Table 2. Summary of student satisfaction with the summer research internship program.

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Question: Tell us how much you agree with each of the following statements. 1 – Strongly Disagree; 2 – Disagree; 3 – Neutral; 4 – Agree; 5 – Strongly Agree.

Activity	**Average Rating**
The internship program was useful.	4.6
I believe that I have the academic background and skills needed for the project.	4.4
The program has helped me prepare for transfer.	4.2
The program has helped me solidify my choice of major.	4.2
As a result of the program, I am more likely to consider graduate school.	4.0
As a result of the program, I am more likely to apply for other internships.	4.8
I am satisfied with the NASA CIPAIR Internship Program.	4.6
I would recommend this internship program to a friend.	4.8

For the group of students working on the myoelectric-controlled robot car, their responses to the question "what do you like most about the NASA CIPAIR Internship Program?" include: "We worked with a lot of cool components! Using the microcontrollers was definitely a first for me, and I'm already excited for other possible applications that I can use them for. I was also really excited that the algorithm I designed (Hold/Pulse) was able to function as well as it did." "The topics were excellent." "The freedom to work at your own pace but keeping in mind deadlines and the opportunity to learn while working." "NASA CIPAIR prepares you for more research programs. You learn how to engineer or build things with the little you have. It helps you to learn a lot of things in the short possible of thing and come out with a results and conclusion. It prepares you for bigger scientific challenges."

In their final report for the project, they concluded their experiences as following: "As a group we were able to gain experience in working as a part of a long term group project. We saw what it was like also work on an interdisciplinary project. This was a key learning experience, as the majority of technological projects involve many different kinds of engineers and scientists. The project included many different fields including biomedical, electrical, computer, and mechanical engineering. One of the key things we all noticed was how important basic programming skills were for the project. Although there were many aspects to the project, much of the key challenges came down to how familiar the group was in programming logic and protocol. This CIPAIR program was very successful in helping us gain practice in a collaborative work environment. By successfully building the EMG remote control system and the actual car, we gained experience in fields of mechanical, electrical and computer engineering, specifically in the world of embedded system design and microcontrollers. Initially we set off to create a very basic control system that allowed for minimal functionality but decided to expand the number of EMG sensors providing the car with a completely functional driving system."

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Summary and Conclusion

The research internship project was successful in helping community college students learn valuable engineering knowledge and skills as well as gain research experience in this multidisciplinary project including acquisition and analysis of bioelectrical signals, programming on microcontrollers, embedded system design, wireless communication, and various analog and digital interfaces. In addition, the project provided a great opportunity for the students to improve their skills in teamwork, communication, writing, presentation, project management, and time management. The outcome of this project indicated that the summer research internship program was an effective method for engaging community college students in engineering research and strengthening their confidence and interest in pursuing an engineering profession.

Acknowledgements

This project was partly supported by the National Aeronautics and Space Administration (NASA) Office of Education through Curriculum Improvement Partnership Award for the Integration of Research into the Undergraduate Curriculum (CIPAIR), Grant No. NNX10AU75G, and by the US Department of Education through the Hispanic-Serving Institution Science, Technology, Engineering, and Mathematics (HSI STEM) Program, Award No. P031C110159.

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Visual Learning Tool for Teaching Entity Relationship Mapping Rules

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Abstract

Based on the authors' experience in teaching the subject of conceptual modeling, many students are unable to master the mapping process for converting an Entity Relationship Diagram (ERD) into its corresponding set of relations. This perhaps is surprising to many since the steps and mechanism for converting an ERD into relational tables are not overwhelmingly complicated and are quite mechanical. Further exploration discovers that the traditional way of describing and teaching the mapping process involves "too much math", as characterized by struggling students, therefore forging a mental barrier for students to learn the mapping concepts appropriately and effectively. This paper describes a new approach to teach the mapping process and rules that "un-math" the math bias associated with the traditional approach. The majority of us are visual learners. Therefore, the proposed approach is visual-based and uses task maps, visual clues, and animations to "un-math" the complexity perceived by students. Specifically, task maps are used to provide an overall roadmap and context of the mapping process while visual clues are embedded into both the task maps and mapping rules to eliminate seemingly complex mathematical notations. Eventually, 3D animations will be utilized to enhance students' learning by turning abstractions into animated environment and in particular to show the movement of primary keys based on the cardinalities of involved relationships. Assessment activities will also be carried out in the future to determine the effectiveness of the new approach.

1. Introduction

Relational database was first proposed by EF Codd in early 1970s. He laid out the foundation of database based on relational theories or set theories. Database is generally considered as a multidisciplinary subject, therefore it is also at times termed as database engineering, because of direct application of computer science and relational mathematics that enables us to solve real world problems. Since database is part of any digital activity that we perform in our daily life thus database remains among the most sought-after and popular subjects taken by students studying in engineering, science, business and technology disciplines. Many, both technical and non-technical, programs (graduate and undergraduate) at times require at least one database course. Usually, such a course introduces the conceptual model of database design (Entity Relationship Model), implementation model (Relational Model) and administration. Teaching a database course to students from different disciplines in one class is always a challenging task, and at the same time, however it can be most rewarding if we are able to explain the transformation process of conceptual model to implementation model in an appropriate manner.

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Based on the authors' experience in teaching the Database design subject in general and conceptual modeling topic in specific, many students have difficulty in mastering the mapping process for converting an Entity Relationship Diagram (ERD) into its corresponding relational schema. Specifically, students seem to have trouble comprehend the overall picture and context of the mapping process and rules. They also have difficulties discerning the arrangement of primary keys based on the cardinalities of relationships; including decision as to when it is necessary to create new relations during the mapping process. This perhaps is surprising to many since the steps and mechanism for converting an ERD into relational model are not overwhelmingly complicated and are quite simple and mechanical. There are also some tools available to perform the mapping. Further exploration discovers that the traditional way of describing and teaching the mapping process involves "mathematical approach", as characterized by some struggling students, therefore forging a mental barrier for struggling students to learn the mapping concepts appropriately and effectively.

This paper describes a new approach to teach the mapping process and rules that is not to be perceived by struggling students as "mathematical approach", the bias associated with the traditional approach. Since the majority of us are visual learners, so the proposed approach is visual-based and uses task maps, visual clues, and animations to avoid the complexity of traditional approach as perceived by students. Specifically, task maps are used to provide an overall roadmap and context of the mapping process while visual clues are embedded into both task maps and mapping rules to eliminate seemingly complex mathematical notations. Our objective is to eventually utilize 3D animations to enhance students' learning, by turning abstractions into animated environment and in particular to show the establishment of primary keys based on the cardinalities of involved relationship types. We also plan to analyze the effectiveness of the new approach by performing assessment activities.

The conventional approach of teaching the mapping process for converting an Entity Relationship Diagram into its corresponding set of relations is reviewed first. Its potential obstacles hindering students in mastering the mapping process is then discussed. In the later section we present the task map outlining the overall mapping process will be proposed. the section that follows is dedicated to incorporate visual clues into both the task map presented in the previous section as well as the mapping rules to eliminate, if necessary, intimidating mathematical notations. Plans for developing animations for each mapping rule is then described. Finally, further research directions will be identified.

2. Conventional Approach for Teaching the Mapping Process

In this section, the conventional approach of teaching the mapping process for converting an Entity Relationship Diagram into its corresponding set of relations is reviewed. For discussions delivered in this paper, the following assumptions are made with respect to Entity Relationship Diagram:

- The basic Chen's ERD notation is used throughout this paper.
- Derived attributes are prohibited.

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- Many-to-many relationships should be used in lieu of associative or intersection entities since associative or intersection entities are not necessary.
- ISA relationships are used instead of supertype and subtype relationships to simply the discussion of the mapping rules.

There are a number of schemes presented in the literature[1,2,3] for converting an Entity Relationship Diagram into its corresponding set of relations. In light of the assumptions made at the beginning of this section, the mapping process is summarized into the following eight rules. The rules are organized as follows: (1) one rule for mapping non-weak (i.e., regular or strong) entities, (2) one rule for mapping weak entities, (3) four rules for converting binary relationships (one for each type of binary relationships, i.e., ISA, one-to-one, one-to-many, and many-to-many), and (4) one rule for mapping n-ary relationships with n >= 3. Here are the eight rules:

- Rule #1: For each non-weak entity *E*, create a relation/table *R*. The name of the relation *R* is the same as the name of the entity *E*. Further, the attributes of the relation is the set of simple attributes associated with the entity plus all the simple component attributes associated with their composite attributes of *E*.

- Rule #2: For each multi-valued attribute *A* of an entity *E*, create a relation/table *R* whose attributes are composed of the attribute corresponding to *A* and the primary key of *E*.

- Rules #3: For each entity *A* which is related to another entity *B* via an "ISA" relationship (i.e., *A* "ISA" *B*), include in the relation corresponding to *A* the primary key of *B*.

- Rule #4: For each binary *one-to-one* relationship *R* between entities *A* and *B* with their corresponding relations *S* and *T*, include in *S*, the primary key of *B*. Further, if the relationship *R* has attributes, include them in *S*. Alternatively, choose *T* in the role of *S*.

- Rule #5: For each binary *one-to-many* relationship *R* between entities *A (1-side)* and *B (n-side)* with their corresponding relations *S* and *T*, include in *T*, the primary key of *A*. Further, if the relationship *R* has attributes, include them in *T*.

- Rule #6: For each binary *many-to-many* relationship *R* between entities *A* and *B* with their corresponding relations *S* and *T*, create a new relation *Q* with the same name as the relationship *R* and include in *Q*, the primary key of *A* and *B*. Further, if the relationship *R* has attributes, include them in *Q*.

- Rule #7: For each *n*-ary (*n*>=3) relationship *R*, create a new relation *Q* and include in *Q* the primary keys of all the entities involved in *R*. Further, if the relationship *R* has attributes, include them in *Q*.

- Rule #8: For each weak entity *E*, create a relation *R* whose schema consists of all the attributes of the entity *E* plus the partial key attributes of weak entity *E*'s owner entity or entities. *E*'s owner entities are those entities connected to entity *E* via identifying relationships (double-diamonds).

  Note that the above rule takes care of mapping identifying relationships. Therefore, no further mapping of identifying relationships is necessary.

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> When mapping relationships involving a weak entity *E*, the key for *E* to be used in the mapping is the combination of all the partial key attributes of *E* and the key attributes of weak entity *E*'s identifying entity or entities.

As one can tell, the above rules are axiomatic and therefore are perceived by some students as mathematical in nature. Consequently, students, especially those who are afraid of math, form a mental barrier preventing them from learning the mapping process properly and effectively. Another difficulty with the above rules is that it is quite hard to relate the entities with their corresponding relations. It is even harder to envision what the resulting relations should look like.

3. The New Approach

Based on the teaching experience of the authors the new approach for teaching the mapping process is evolved. This approach entails three components, the first component is a task map providing an overall roadmap and context of the mapping process while the second component is a set of programs animating each of the eight mapping rules. The third component is to incorporate visual clues into the concept as well as the eight mapping rules. In the following sections we explain our approach by first explaining all the tasks that are part of the process, then showing how we envision these tasks using animation and finally presenting the visual clues for each rule.

3.1 **Task maps**

The first component of the proposed new approach is a task map, based on the notion of concept maps, providing an overall roadmap and context of the mapping process. A concept map is a graphical tool and is typically used to organize ideas and knowledge by connecting related concepts with arrows. The notion of task maps used in this paper organizes related tasks instead via arrows and is adopted to present an overall plan for the mapping process. Hence, it should be introduced before the mapping rules are explained. As depicted in Figure 1 below, the task map offers students a clear "divide-and-conquer" plan for converting an Entity Relationship Diagram to its corresponding relational database schema. Specifically, the task map divides the process into two tasks, namely "map entities & attributes" and "map relationships". The task of "Map entities & attributes" in turn is accomplished by mapping non-weak entities and attributes, mapping weak entities and attributes, and mapping multi-valued attributes. On the other hand, "map relationships" is achieved by mapping binary relationships and mapping n-ary relationships. Finally, "map binary relationships" is carried out based on the four different types of binary relationships. The task map also helps student remember the mapping concepts better. Note that the concept introduced here is to be read from top to bottom by following the arrows. Tasks on the leaf level correspond to the eight mapping rules discussed in Section 2. However, it does not imply concurrency with respect to tasks of the same level, nor does it assume an order. For example, "Map Binary Relationships" and "Map n-ary (n>=3) Relationships" appear on the same level on the task map. It does not signify that these two tasks have to be performed at the same. Nor does it assume that "Map Binary Relationship" has to be done before "Map n-ary (n>=3) Relationships" or vice versa.

3.2 Animations

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The second component of the proposed new approach is composed of a set of 3D animation programs for each of the eight rules discussed. The idea is to demonstrate the mapping rules in an animated environment to show the creation of relations and highlight the movement of primary keys based on the cardinalities of involved relationships. Figure 2 is a very basic sketch illustrating the mapping of a one-to-many relationship type. Note that the actual animation programs are much more effective in serving the intended purpose than the sketch provided. There actual development is the subject of future work.

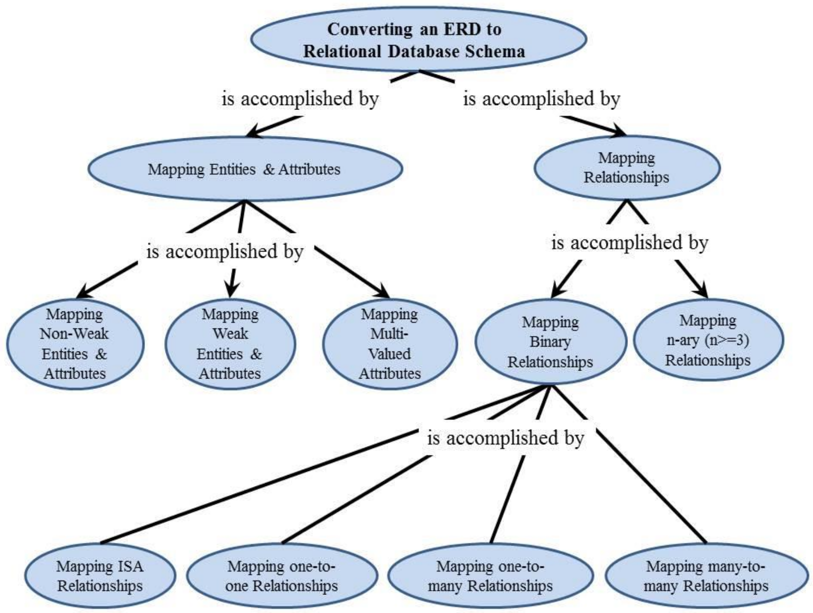

Figure 1 – Task map outlining the Mapping Process

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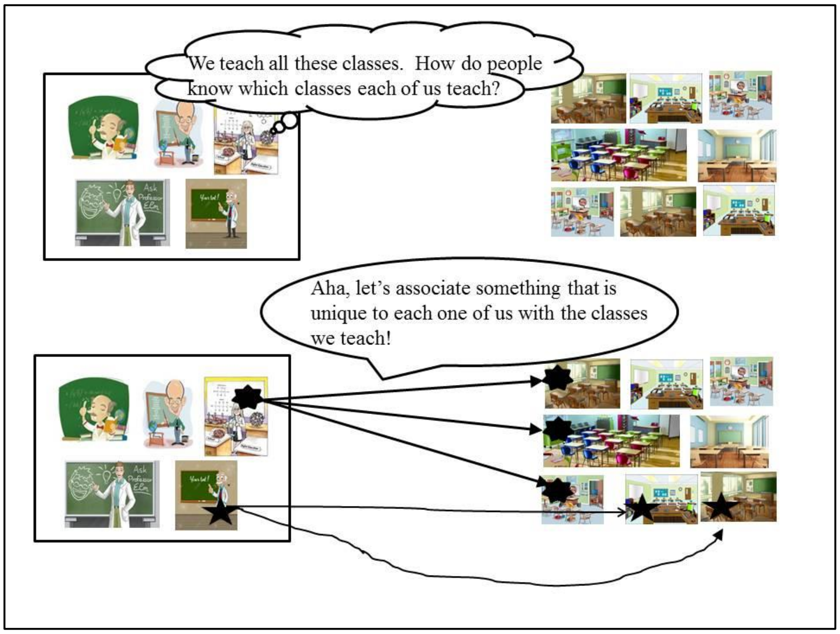

Figure 2 – Animation Sketch

3.3 Visual Clues

Most people are visual learners. Research shows that graphic and visual objects help students comprehend complex ideas and subjects. Further, they improve student retaining concepts taught in the classrooms[4]. The second component of the proposed new approach involves incorporating visual clues into the task map as well as the eight mapping rules. The goal is to "un-math" the mathematical complexity embedded in the eight mapping rules as perceived by students by replacing mathematical notations with visual objects whenever possible. The task map with visual clues is illustrated in Figure 2 below. This task map should be used instead of the initial one presented in the previous section.

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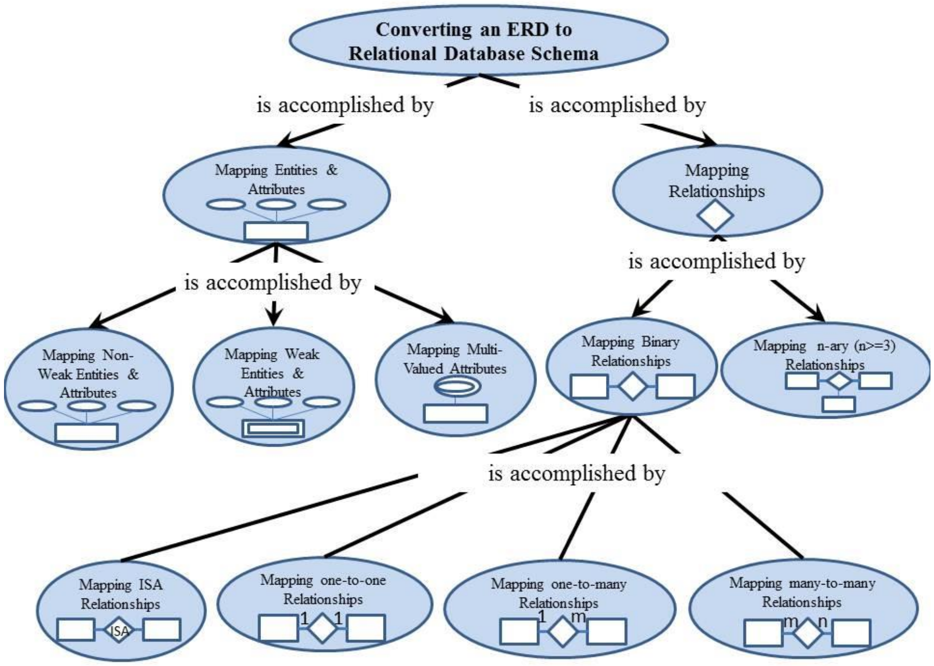
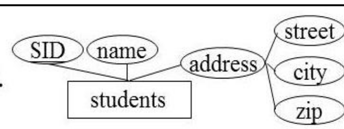


Figure 3 – Task map with Visual Clue

The eight rules with visual clues are presented in Figures 4 through 10. Take rule #1 as shown in Figure 3 as an example, first of all, the mathematical notation has been removed from the rule. Instead, actual examples of an entity and its corresponding relation are included in the rule as visual clues. As a result, students are able to the entity with its corresponding relation. Furthermore, the visual clues serve as a specific example for the rule as well.

For each non-weak entity (e.g. 

), create a database relation/table. The name of the relation is the same as the name of the entity. Further, the attributes of the relation is the same as the set of attributes associated with the entity (i.e.,

students

SID	name	street	city	zip

).

Figure 4 – Rule #1

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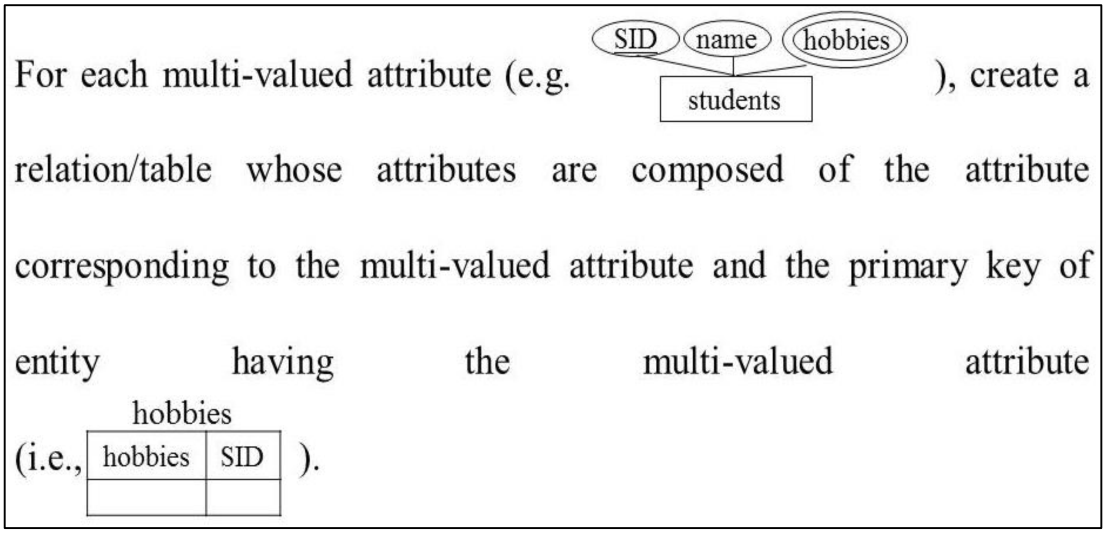

Figure 5 – Rule #2

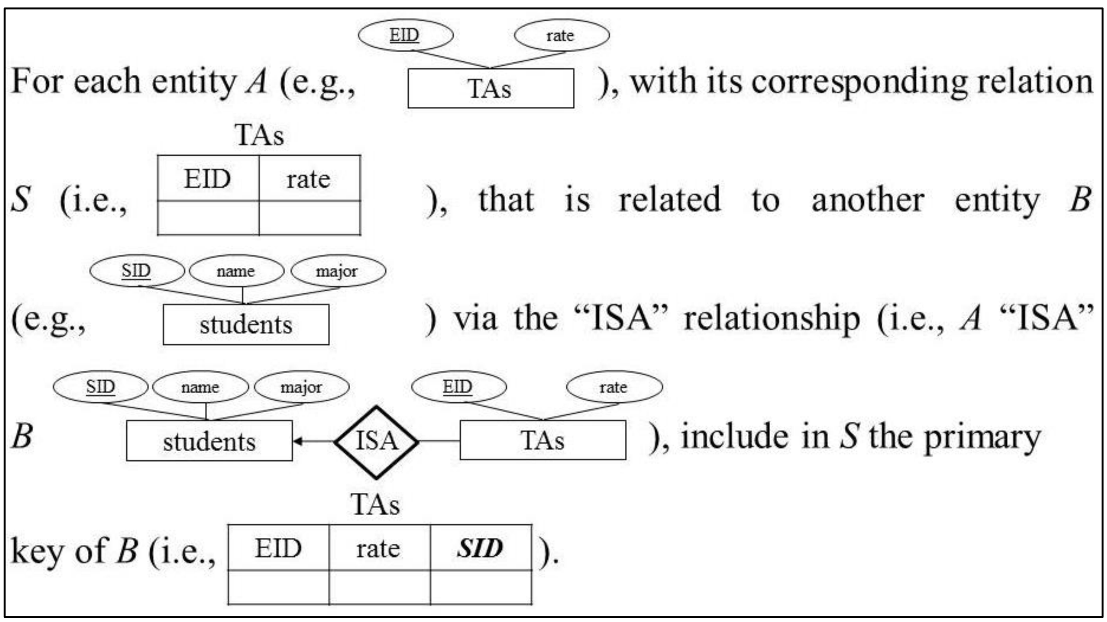

Figure 6 – Rule #3

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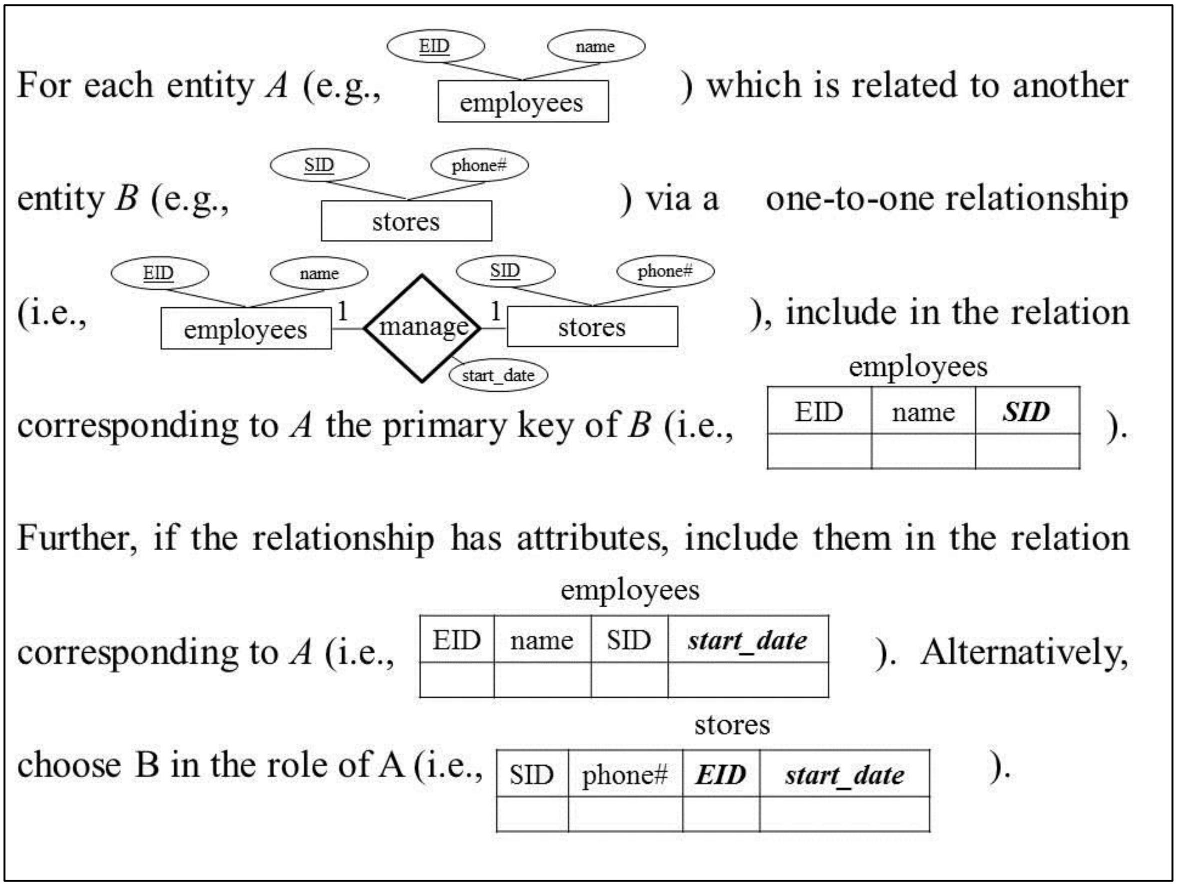

Figure 7 – Rule #4

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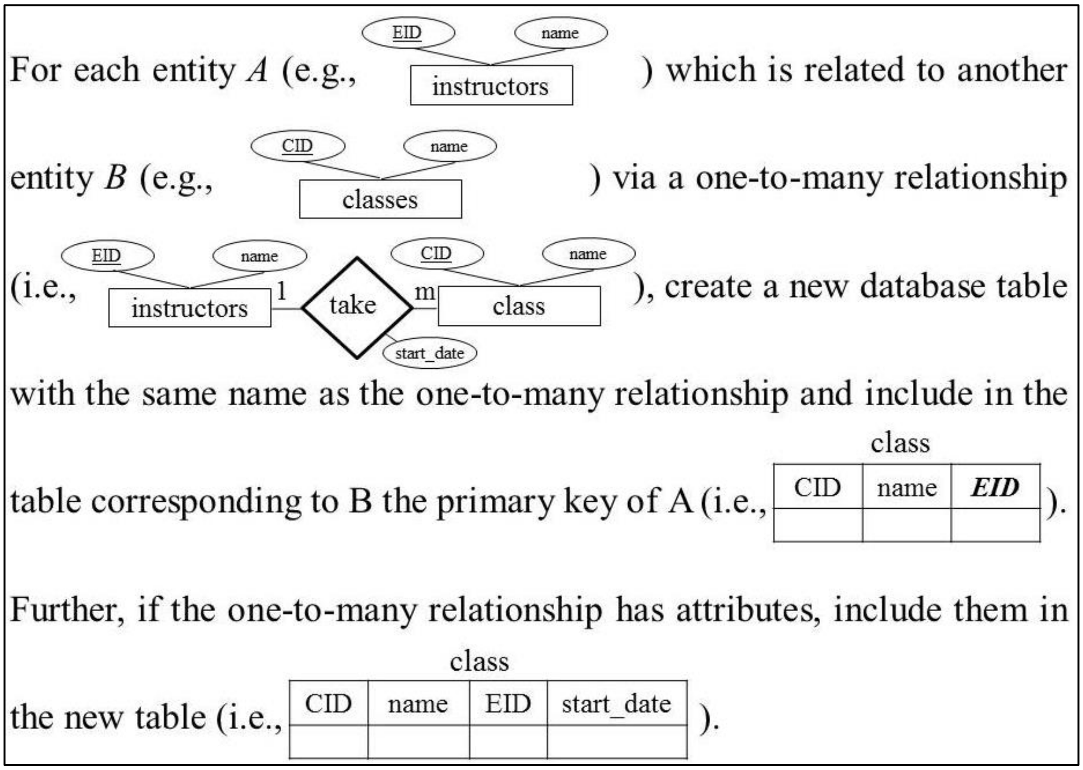

Figure 8 – Rule #5

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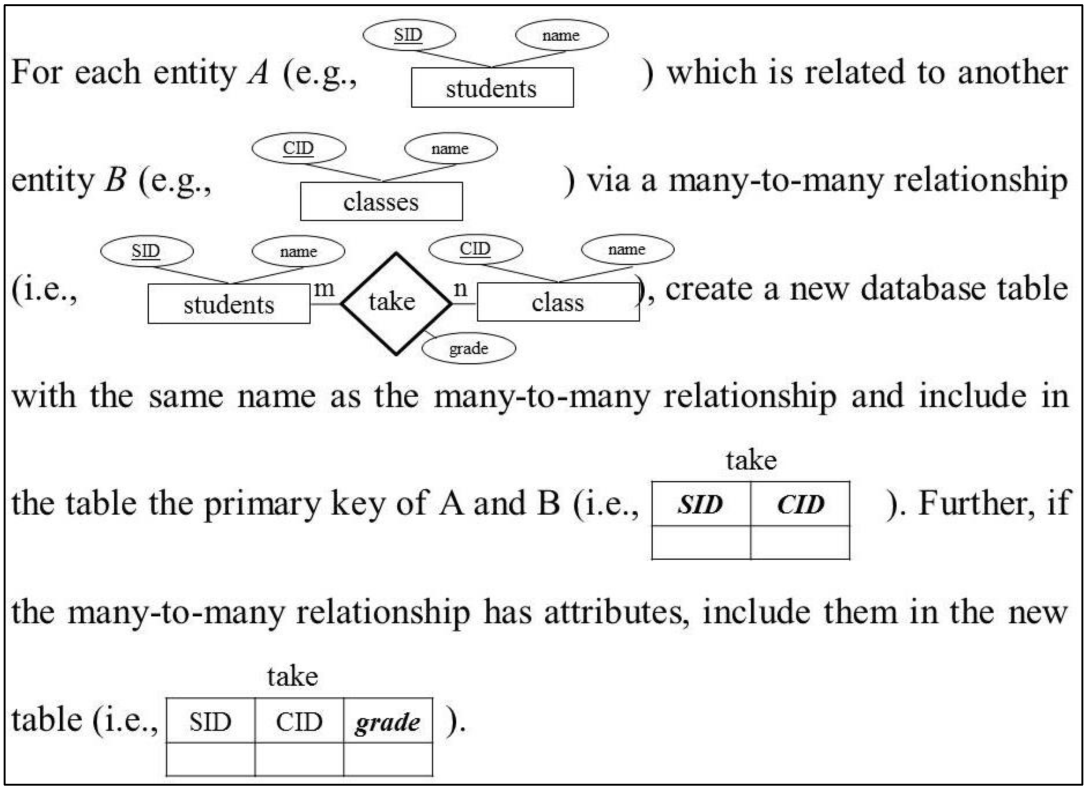

Figure 9 – Rule #6

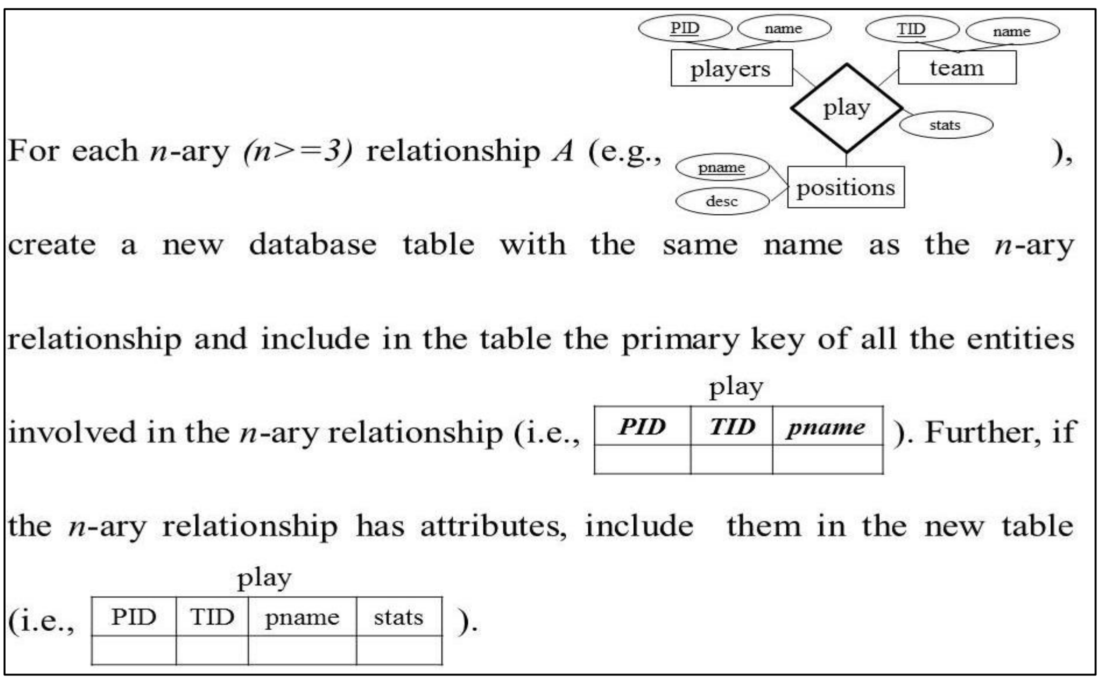

Figure 10 – Rule #7

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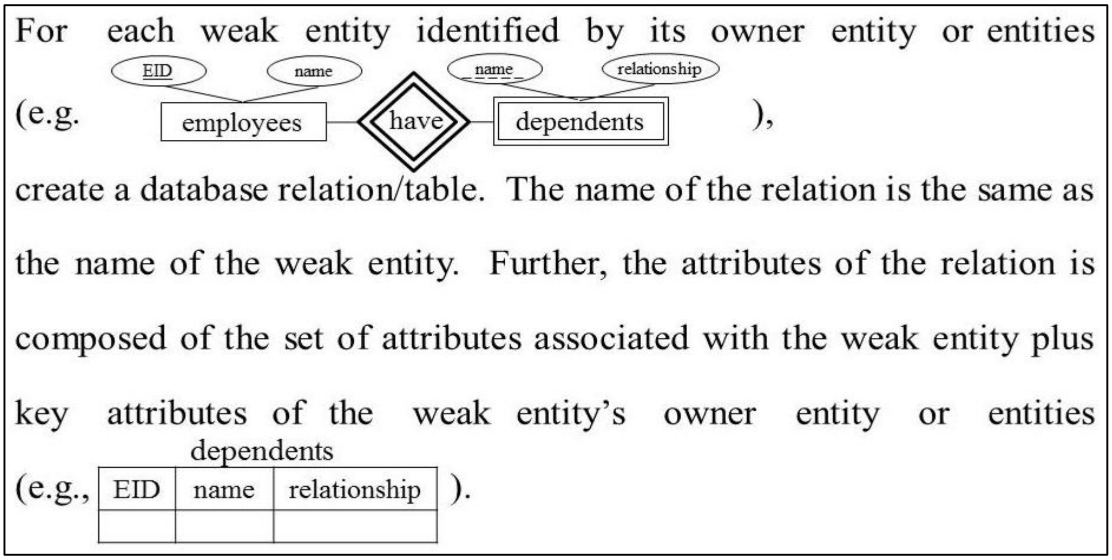

Figure 11 – Rule #8

1. Conclusion and Future Work

In this paper, a new approach for teaching the mapping process for converting an Entity Relationship Diagram into its corresponding set of relations is introduced. The new approach improves upon the conventional teaching method by incorporating task maps, visual clues, and 3D animations as well as removing unnecessary mathematical notations.

What's presented in this paper is just the beginning. As noted earlier, further research activities include the actual development of 3D animation programs by using Alice. Further, exercises will be developed and classroom activities will be carried out to assess the effectiveness of this new approach. Specifically, classes will be divided into two groups and one group is taught the mapping process by following the conventional approach while the other group with the new approach. Afterwards, the students will be given the same assessment exercise to gauge the effectiveness of the new approach.

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3D Printing as an Enabling Platform for Cross-Disciplinary Undergraduate Engineering Education and Research

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Abstract

Expanding undergraduate students' learning beyond the traditional classroom and exposing them early on to research training or hands on project have been proven to be an effective means to prepare them to be engaged learners and sophisticated engineers. Faced with increasingly complex engineering problems that are inextricably intertwined across engineering disciplines, an engineer's traditional comfort zone of 'individual discipline' no longer exists. In present day's context, an engineer needs to possess cross-disciplinary skills in order to effectively tackle complex engineering problems that are multidisciplinary in nature. For institutes of higher learning, this makes the task of creating meaningful and educationally relevant cross-disciplinary student research projects all the more challenging yet highly impactful if done successfully. In this paper, we describe a cross-disciplinary project where 3D printing and specifically, the conceptualization and prototyping of a temperature-controlled enclosure for a 3D printer, serve as an enabling platform to catalyze learning of the essentials of team-based, interdisciplinary engineering research and development. The goals of the project are: (i) to investigate the influence of a controlled temperature environment on the print quality of 3D printed parts, and to optimize the print quality accordingly; (ii) to allow beginning engineering students with little prior engineering training and 3D printing knowledge to complete a product development cycle of problem definition, literature research, design concept generation, prototyping, and testing under guidance. To this end, a team of four community college mechanical engineering sophomores, working under a NASA Curriculum Improvement Partnership Award for Integration of Research into Curriculum (CiPAIR) grant, were tasked with conceptualizing, designing, and prototyping a closed-loop temperature-controlled enclosure that encased a 3D printer using commercially available parts, as well as testing the properties of parts printed in such a controlled environment. Under the supervision of a graduate student mentor and a faculty mentor, the team learned mechanical design using SolidWorks, material selection, hands on metal and plastics fabrication, heat transfer, as well as microcontroller programming using Arduino to build a temperature-

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controlled enclosure made of acrylics with built-in heating and cooling elements. Parts made of poly-lactic acid were printed and tested with and without temperature control. Various quantitative tests were performed on parts printed in a non-enclosed versus a temperature-controlled, enclosed environment—including tensile test, hardness test, and surface roughness measurement—to determine the quality of prints and the effectiveness of the enclosure. Both the tensile test and hardness measurement showed positive correlation between controlled temperature and mechanical properties of the printed poly-lactic acid. Comparing samples printed with and without temperature control, the latter allowed for the optimization of tensile strength and hardness. Specimens that were printed in a controlled temperature range of 35-37°C showed the largest improvement in both tensile strengths and hardness as compared to specimens printed without temperature control, or printed at lower or higher controlled temperatures. Exit interviews with students showed a deepening of interest in engineering as a career, a significant increase in professional confidence, and strong interest in pursuing graduate study in engineering.

1. Introduction

Three-dimensional printing is a rapidly developing technology that revolutionizes the design and fabrication process of products by increasing the speed and efficiency in which complex, three-dimensional (3D) objects can be created[1,2]. However, given the technology is relatively new, there are many aspects to 3D printing that still require optimization in order to achieve a high-quality print within a reasonable time and cost. Many 3D printers extrude the thermoplastics acrylonitrile butadiene styrene (ABS) or poly lactic acid (PLA) as print materials and create a 3D object by extruding many fine layers over one another until the object is complete[2]. These polymer thermoplastics behave similarly, yet adhere to the print bed and previous layer of material best in material-specific environmental temperatures and conditions. In order to prevent delamination and to increase the print quality, the optimal environment temperature in an 8 ft^3 enclosure is explored. A majority of current 3D printers have heated extruder heads and heated print surfaces, but these only provide local heating and cannot maintain the optimal temperature across the entire print. As a result, a temperature-controlled enclosure could be a beneficial addition to a 3D printing setup in order to increase part-to-part consistency.

Controlling and maintaining the environmental temperature during a print improves the overall quality of the print for multiple reasons. 3D-printed objects tend to have issues with interlayer adhesion if they contain more than a few layers in z-axis height. This is primarily caused by the temperature gradient between the layer on the print surface and the layer freshly deposited from the extruder. At lower z-axis ranges, the heated print bed is able to heat most layers evenly. However, beyond a certain number of layers, the temperature varies and can fail to meet the minimum temperature required for proper inter-layer adhesion. Coupled with the temperature gradient, this can lead to delamination when the printed object is complete, as well as warping of the print surface of both the main and support structures of the print. Maintaining an elevated environmental temperature reduces the possibility of warping and delamination along with

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improving the integrity, uniformity, and strength of printed structures. Surface finish can also be an issue with 3D printing, due to the nature of fused deposition modeling (FDM)[3], which is the most common printing method in which plastic is deposited in strings, layer by layer. Printed surfaces in direct contact with the heated bed consistently have a smoother texture and glossier appearance than surfaces not in direct contact due to the elevated temperature of the bed, which promotes reflow and hence polymer chains movement. When exposed to consistent and higher temperature throughout the duration of the print, the surface textures of all external surfaces can be improved with a more consistent and smoother surface texture. By rectifying each of these issues, a closed-loop feedback temperature controlled enclosure can prevent warping and provide a smoother surface finish, leading to higher overall print quality.

2. Project Scope

A team of four community college engineering sophomores were tasked with conceptualizing, designing, constructing, and testing a temperature controlled enclosure for a 3D printer (PunchTec Connect XL)[4]. The overarching goal of the endeavor was to determine if an enclosure, with or without active temperature control, could improve the print quality. Without active temperature control, it is reasonable to expect that an enclosure may increase print quality by minimizing convective air flow that could potentially: (i) introduce instability in the still-viscoelastic polymeric extrudate during deposition, or (ii) deposit dust/debris particles in the still-malleable print material. On the other hand, the primary rationale behind implementing active temperature control is to explore ways to reduce part warpage during and after printing. While most 3D printers with heated beds can mitigate warping effects through the completion of printing, the cooling rate after completion of the printing is generally uneven within the part. The bottom of the part which is in contact with the heated bed during and post-printing will cool at a lower rate than the sections above the bed[5]. When the part is finally removed from the bed and allowed to cool completely, residual stress through the thickness of the part will form. As such, the implementation of a temperature-controlled environment allows for slower, controlled and more uniform cooling throughout the part, and could potentially mitigate through-thickness stress gradient within the part.

The major aspects of the project included the enclosure, heating elements, environment temperature measurement, temperature control, user interface, and testing. The students' overall goal was to create an enclosure that had an intuitive user interface that allowed for a desired temperature to be set easily. Once the desired temperature was set, the enclosure would be heated to the desired temperature and be able to maintain this temperature while minimizing air movement from the heating subsystem. With the construction of the enclosure completed, the testing and actual research with regards to the effects of the enclosure could then proceed. Based on the hypothesis that controlled environment could enhance quality and properties of a print, the

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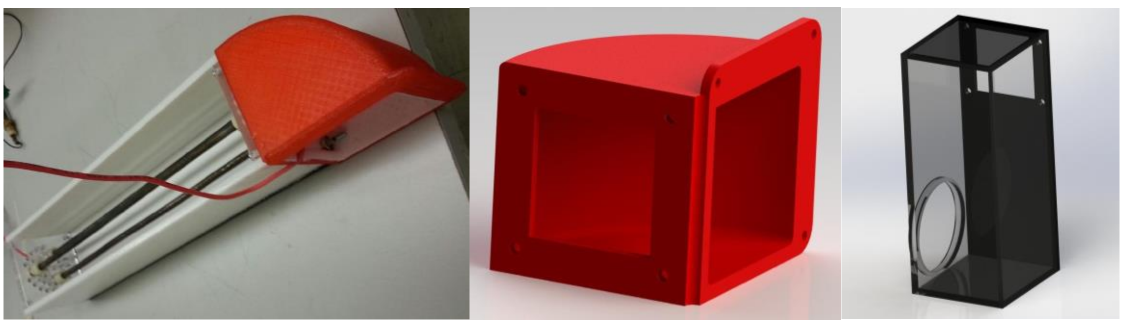
students determined a testing scheme that involved tensile tests, hardness tests, and surface roughness tests to elucidate the effect of temperature control on key mechanical properties.

(A) Design and Fabrication

Before building the enclosure, the students performed materials selection and developed components specifications. One of the most important areas of focus was the walls of the enclosure. The walls had to tolerate elevated temperatures while being cost-effective and transparent. It was decided that acrylic was a suitable material choice given its being capable of withstanding temperatures ranging from -40° to 60°C while maintaining its mechanical rigidity and strength. The acrylic sheets were purchased in 24 inches by 24 inches sheets with a thickness of 0.25 inches and bonded together with acrylic weld and metal *L* brackets. To facilitate access to the 3D printer within the enclosure, a door was attached to a reinforced section of the enclosure.

For the heating element, a product that could heat and cool in a short period of time was necessary. The team decided to use three heating elements salvaged from a toaster oven. The repurposed heating elements are powered by 120V AC which required special circuitry in order to be controlled with the Arduino microcontroller the team intended on using. The heating elements were housed in a secondary enclosure made from acrylic that was spray-coated with a ceramic coating to maintain the integrity of this secondary enclosure (Fig 1a). The heating system consists of a 12V DC CPU cooling fan to circulate air through a heated chamber containing three heating elements (Fig 1a) into the 3D printer's enclosure. The heating chamber is connected to the enclosure with a custom PLA duct (Fig 1b) and reheater duct (Fig 1c). The PLA duct was printed using the PunchTec 3D printer and the reheater system was constructed from acrylic sheets.



(**a**) (**b**) (**c**)

Figure 1. (a) Heating element, (**b**) SolidWorks drawing for the vent, (**c**) Reheater.

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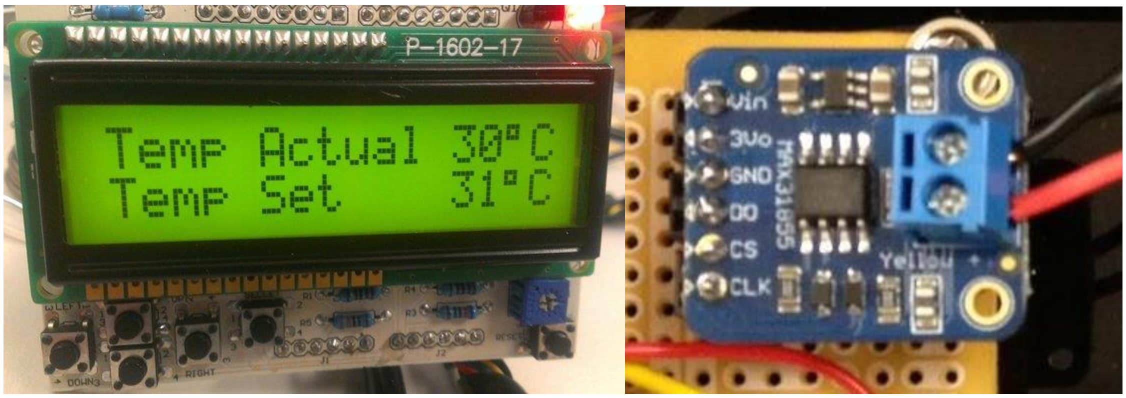
In order for the user to set and monitor the temperature within the enclosure, the students added an LCD Button Shield Display manufactured by LinkSprite. It contains a 16x2 character display with a green backlight, as well as five programmable buttons and one reset button (Fig 2a). To monitor the temperature inside the enclosure, a wire-style K-type thermocouple was implemented. The thermocouple output was converted to a usable signal using a Max 31855 thermocouple amplifier breakout board (Fig 2b) from Adafruit Industries. In order to control the CPU fan and the heating elements with a microcontroller, a MOSFET was implemented for power control. As previously mentioned, an Arduino microcontroller was used as the processor for the control system (Fig 3).



(**a**) (**b**)

Figure 2. (**a**) LCD button shield by LinkSprite, (**b**) Max 31855 thermocouple amplifier

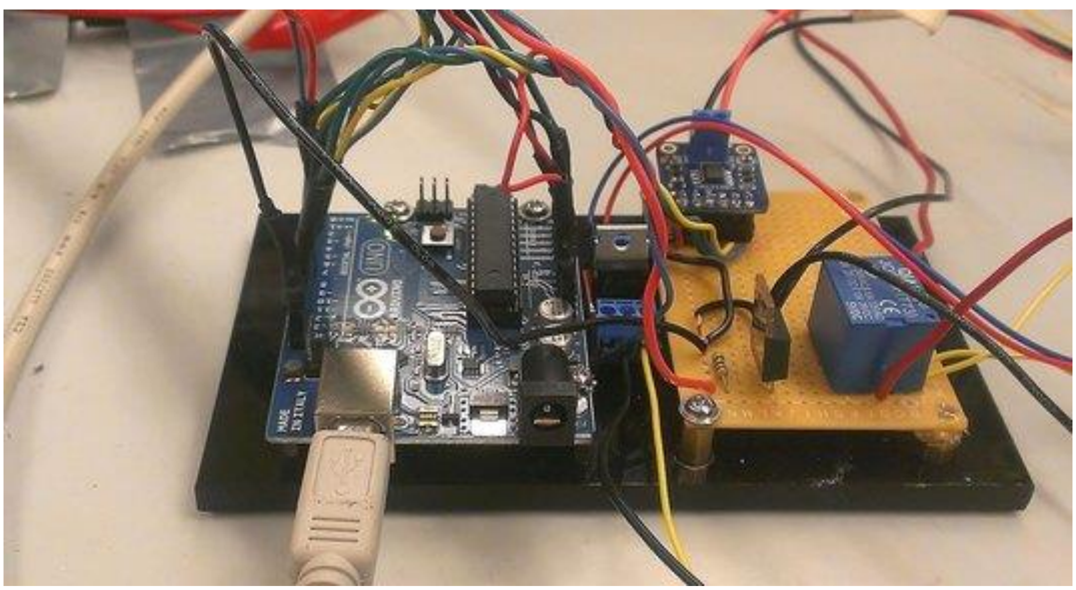


Figure 3. Arduino Uno connected to the thermocouple, LCD screen and heating system.

(B) Circuit Elements

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According to the original design plan, the circuit for the heating elements was to be composed of a Power Control MOSFET. Since the heating elements require an AC current to be powered the team wanted to see if pulsing the DC power would create an artificial AC wave that would power the heating elements. This approach proved to be ineffective and left the heating elements underpowered. The team determined that this was due to the coils not receiving enough amperage. Because of this the team opted to upgrade the power supply to a 12V 30A model. However, even with the upgraded amperage, the heating coils were still under-powered. After consulting with an electrical engineer, it was determined that using AC power was necessary. For this approach to work, there needed to be a safe way for the Arduino microcontroller to control the AC current sent to the heating coils.

The new approach to control the heating coils utilized an IRF510 MOSFET which was used to switch a relay. A schematic for this circuit was created using PSpice (Fig 4). This circuit worked with a 5V DC signal sent from the Arduino microcontroller to the IRF 510. The IRF 510 then used that signal to close a circuit between the relay and a power supply, allowing roughly 12.6V to be sent to the relay. The relay we used required 12V to actuate the internal coil, which, when activated, created a magnetic field inside the relay. This magnetic field then closed an internal switch inside the relay which we used to run AC current. Once the internal switch is actuated, the AC current flowed to the heating elements. With this setup there was less potential for failure; however, the team also had less overall control of the heating elements. After some initial tests, the team concluded that further control of the heating elements was not needed, and chose the relay circuit.

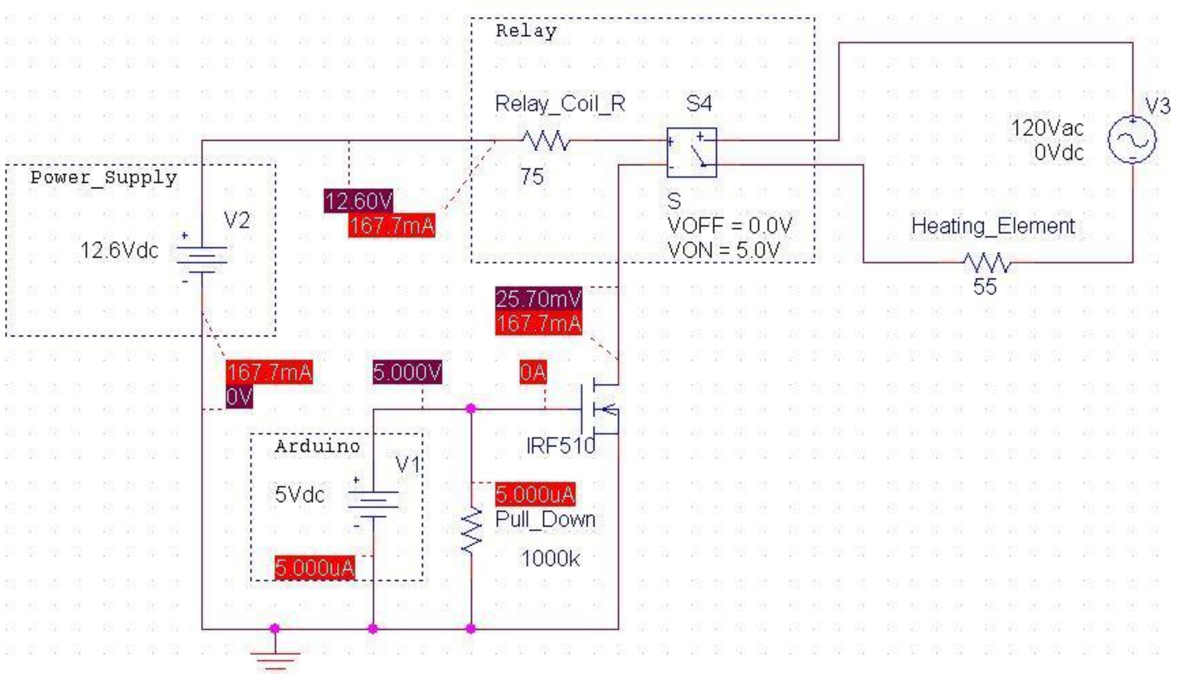

Figure 4. Relay circuit design using PSpice.

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(C) Tensile Testing

By determining tensile strength it was possible to determine the important material properties of the printed parts. This provided a useful comparison and method of determining whether or not the enclosure was effective. To determine tensile strength, an Instron 3369 tensile test system was utilized. The test prints were clamped down by their ends and gradually pulled apart in an elongating manner. The data, when graphed, displayed stress vs. strain characteristics that revealed interesting trends and properties of the material.

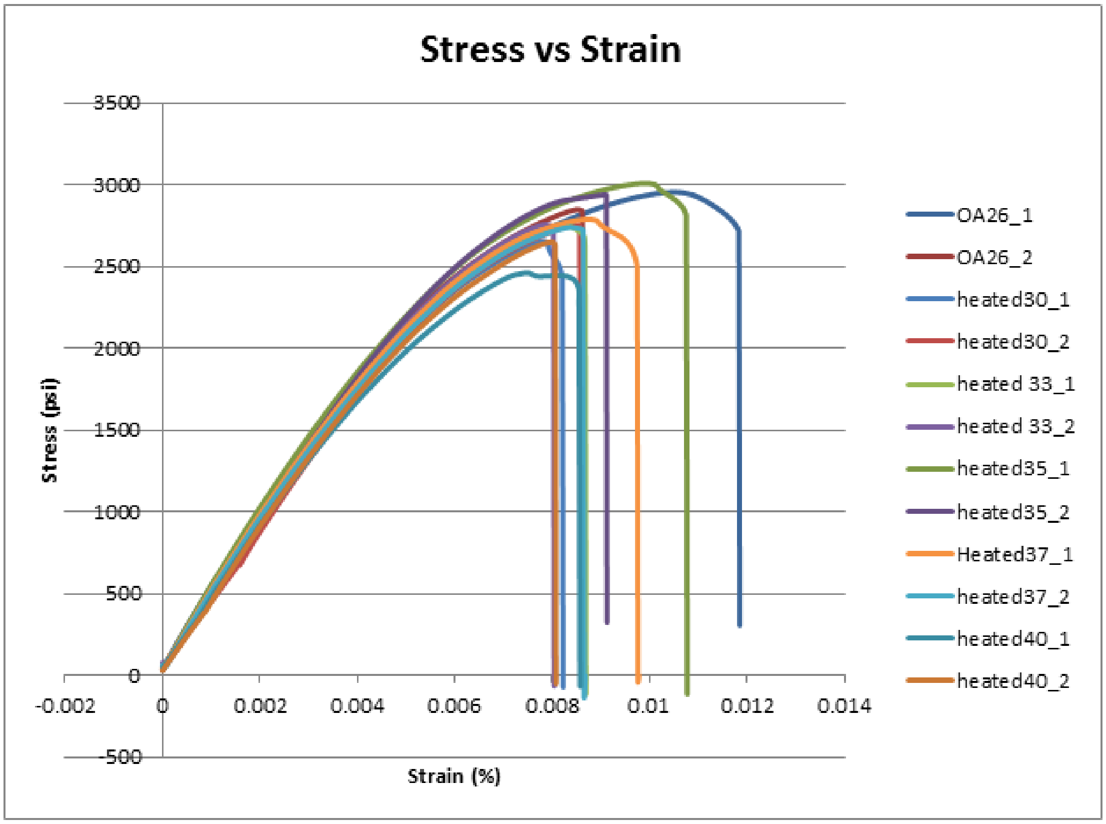

Figure 5. Tensile Test graphs of specimens

In the stress vs. strain graph (Fig 5) there are certain trends that reveal critical information about the test material. There are four stages that are revealed once a material has been tested: the elastic stage, the yielding stage, the plastic and strain hardening stage, and the necking stage. Each stage reveals a critical limit that provides important information about the material. These specimens performed differently than common polymer specimens. They experienced a significant amount of elastic behavior when compared to normal bulk PLA specimens. The 3D printed specimens presented here were printed with 20% hexagonal fill patterns. With normal bulk PLA it is typical to see significant plastic deformation, however in the presented specimens we see almost equal parts elastic and plastic deformation prior to failure. Polymers under tensile load typically deform plastically. The brittle nature of the presented specimens signifies that

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either the internal structure of the specimens or the heat processing of the printing process caused this material (PLA) to become significantly more brittle.

The tensile strength graph suggested that the heated enclosure increased the tensile strength a small amount at a certain temperature. There appeared to be a zenith of tensile strength values at the optimal temperature of 35°C. Beyond this temperature, the tensile strength would begin to decrease rather than increase the tensile strength of the PLA sample test print. The strongest sample which was made at 35˚C, withstood a max stress of 3009 psi at a strain of .9905%. The maximum average stress was supported by the 35˚C prints, which held a combined average 2974 psi. As mentioned, tests beyond 35˚C such as 40˚C tend to lower the tensile strength to a point even below that of the open air (26˚C) prints, which withstood an average of 2900 psi stress, the second highest value. The samples heated to 40˚C averaged a maximum stress of 2556 psi, while the samples heated to 30˚C held an average maximum stress of 2704 psi. If the temperature is above 40°C, the feeder of the 3D printer would be jammed--the plastic became too soft to be pulled from the spool. The 35˚C print could have held more stress than the other samples because of stronger lamination between layers above the heated bed due to an optimal environmental temperature. However, this did not explain why the 30˚C sample print held at least 6.8% less stress than the open-air print and 35˚C print. The 40˚C sample prints were the weakest prints out of all of the samples, which may have been caused by the environmental temperature being too high for the extruded thermoplastics to laminate and solidify correctly. It is important to note that the 35˚C prints were only capable of holding 2.5% more stress than the open-air print, which is a difference too insignificant to draw any definitive conclusions about whether the heated enclosure affects the print tensile strength.

3. Learning Aspects for Students: Research Experience

Participation in a research project during the early-to-mid college career provides a learning environment where lectures are reinforced with hands-on experiences and new topics outside of lectures are learnt. While most lab classes that are paired with lectures provide a simplified version of a true research lab environment, actually joining and working on a research project allows students to work on and explore topics outside of the normal curriculum. By allowing students to explore their own interests, the students seemed to become more interested in simply expanding their knowledge base. This includes trying to get more out of their classes by studying more and, in general, becoming more enthusiastic about learning. During the course of the project it was apparent with two of the students that they had a transition from asking "How do we fix a problem?" to "Why does this problem exist?". This transition partially included the students performing more literature searches on their own and trying their own little experiments while trying to complete project related tasks.

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This project allowed these four students to experience a research project that was directly related to their interests. Despite not being of their own conception, the project idea was determined with consideration to what is a new and interesting technology that requires some deep learning into various subjects. 3D printing fit these profile requirements very well. While the obvious project would have been to have them build a 3D printer and study how various modifications altered its performance, this would have taken too long and been outside of the allotted budget. The question was raised of whether enclosed printers produce higher quality prints due to the controlled environment. This was relatively easy to explore as it required an enclosure and a temperature controlling mechanism. The project therefore necessitated both electrical and mechanical aptitude. Seeing as how all the participants were mechanical engineering students, everyone's skill set was tested and expanded by the project. This simulated a long term research project or a new and challenging job.

Parts of this project were beyond the students class based knowledge at the time of the project. Only two of the four students had taken electrical circuit classes and their knowledge of thermodynamics was limited. Considering both thermodynamics and circuit design and construction were important for this project, the students seemed to approach the project as if it was above their skill level. Once it was demonstrated by the advisor on how to figure out what they needed to know and where to look, the students quickly picked up their work pace and enthusiasm for the project. As the project progressed the students self-regulated and almost automatically assigned or picked up specific tasks based on their skill sets and interests.

The biggest task, by far, was the construction of the electronic control unit for the project. With limited previous experience (one student had used an Arduino prior and taken a circuits class and one other had simply taken a circuits class), the students quickly realized that this needed to be the initial focus for the project. At first the students were very ambitious and were trying to work through all the electronics at once. However, from the previous experience of the advisors, the students quickly realized that breaking the electronics down into smaller projects that could be combined later was a much more efficient means of progress.

One of the initial problems that the students overcame was the heating element. The original heating element that was purchased for the project was not sufficient. While there were no calculations performed to determine this, the students devised small tests of the heating element to determine if it would be capable of heating a large enclosure. The test that the students constructed was to apply the heating element to the heatsink and measure how hot certain points (moving away from the heating element) on the heatsink became. Due to a significant temperature drop across the heatsink signified that this heating system would not work.

While the students had not been formally introduced to circuit design or thermodynamics, they were able to learn on their own in order to construct a simple experiment to test whether a

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component satisfied their design constraints. Alongside this test, the students also decided to implement a reheating system in order to increase the efficiency of the system. While the original design of pulling exterior air through the heating element system worked, it took too long to heat up. In order to solve this the students read about and implemented a reheating system, which is significantly more advanced topic than any of the classes had covered for any of the students.

By providing a hands on task for the students to explore that was related but more advanced than anything covered in their classes, the students were forced but internally driven to explore and conquer these more advanced topics.

4. Students' Responses and Survey Results

In order to gage the effectiveness of the summer research program, a post-completion exit survey was conducted. The survey was administered to 16 community college students, four each from the mechanical engineering, civil engineering, electrical engineering and computer engineering groups. Two sets of responses are summarized in Tables 1 and 2. While it appears that overall the projects were pleasing and useful to the students, some of the most important aspects of the projects to the students were not the actual projects themselves but more the skills and knowledge that was gained from the experiences. For example, "performing research" scored lower than "creating a poster presentation" or "working as part of a team". Skills such as technical report writing and proper presentation techniques are crucial. These skills can be the difference of high quality work being appreciated or disregarded. While projects and internships, such as the NASA CiPAIR, are platforms for skill development, they also allow for intrapersonal development. For some in this program it helped determine whether or not they wanted to go pursue a graduate degree. The students who were interested in the how and why certain results occurred and subsequently pursued information to determine those answers, were most interested in future research.

Table 1. Summary of student responses to the post-program survey measuring the perceived benefit of participating in the research internship program.

Question: As a result of your participation in the program, how much did you learn about each of the following? 1 – Nothing; 2 – A little; 3 – Some; 4 – Quite a bit; 5 – A lot.

Activity	Average Rating
Performing research	4.3
Designing/performing an experiment	4.5
Creating a work plan	4.7
Working as a part of a team	4.6

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Writing a technical report	4.5
Creating a poster presentation	4.6
Making an oral presentation	4.5

Table 2. Summary of student satisfaction with the summer research internship program.

Question: Tell us how much you agree with each of the following statements. 1 – Strongly Disagree; 2 – Disagree; 3 – Neutral; 4 – Agree; 5 – Strongly Agree.

Activity	**Average Rating**
The internship program was useful.	4.6
I believe that I have the academic background and skills needed for the project.	4.4
The program has helped me prepare for transfer.	4.2
The program has helped me solidify my choice of major.	4.2
As a result of the program, I am more likely to consider graduate school.	4.0
As a result of the program, I am more likely to apply for other internships.	4.8
I am satisfied with the NASA CIPAIR Internship Program.	4.6
I would recommend this internship program to a friend.	4.8

Aside from the learning of topics that extended past their classrooms, the students learned skills that were applicable in a wide variety of situations. The program required the presentation of each group's project in both oral, written, and poster forms. For most of these students in the mechanical engineering group, barring one student who participated in the program the previous year, it was their first time presenting a research project. It should be noted that due to this group's commitment and work, they earned themselves the "Best Poster" award at the SACNAS Conference. In the post project questionnaire one student specifically called out the fact that he "had the opportunity to improve [his Solidworks] and communication/presentation skills." While the students may have presented in front of their classes for class based projects, they had never

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had the opportunity to present at a conference or to a large (in comparison to a standard class) audience of their peers.

Other group members felt that one of the most important lessons they learned from this project was time management. In today's world, time management seems to almost be an unimportant aspect of daily life considering the regular use of electronic devices to alert us to where we need to be. However, standard time management skills do not apply to research projects. Every project may start off with a well devised schedule, but issues always arise. Because of this, time management turns into crisis management very quickly, and the students in this group experienced this early on in the project with the heating element. While the heating element issue took longer than planned to get right, the skills learned of how to deal with issues was comprehended quickly by the group and future issues such as the heating rate seemed to be dealt with in a rapid and efficient manner without getting too far off of schedule. This is also demonstrated in Table 1 where "creating a work plan" received an average value of 4.7, the second highest result in the post-internship questionnaire.

All of the skills learned during the course of this project were focused, despite being unintentional, around preparing the students for future research positions specifically at the graduate education level. While this was a short term project, elapsing approximately 3 months, it provided the students with a chance to determine whether or not they enjoyed the research environment and if they felt that graduate study would be something they are interested in. Considering many people go into graduate study without previous research experience, this was a great opportunity for the students to figure out how to proceed in their studies. By integrating various topics (thermodynamics, heat transfer, mechanics, electrical circuits, and mechanical design) the student were shown that while they may intend on focusing in a specific area, broadening their horizons to topics outside their comfort can be fun and very interesting. However, while some of the students answered that they were now more interested in pursuing a graduate degree, some learned that graduate school may not be for them. This is signified by the fact that this aspect was rated the lowest with a score of 4.0.

5. Conclusion

Programs such as the NASA CiPAIR program provide a mutually beneficial learning environment to educators and students alike. Throughout the duration of the 3D printer enclosure project, the students advanced their knowledge beyond the theoretical level that is provided in a classroom environment. While the students are benefitting from a hands-on learning environment, the primary investigator and/or mentor to the students gets to explore topics that may not normally be pursued as the project may be too simple and short for a regular research assistant. While the enclosure for the 3D printer was a complex task it would not have otherwise been created as other lines of research (such as new advanced print materials) would be

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considered more impactful and economically viable. However, the enclosure proved to be beneficial for creating more uniform samples along with provided a research project that the students could experience and be involved in from start to finish.

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Experience Assessing Student Performance using Daily Quizzes in a Third-Year Civil Engineering Course

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Abstract

The paper describes our experience using daily quizzes to assess student performance in a third-year civil engineering course on geotechnical engineering. We administer most of the quizzes during class. Students typically have five to ten minutes to complete each quiz. Therefore, the quizzes require a relatively small fraction of the time available for in-class lessons, discussions, and problem solving. The total quiz score constitutes the majority of a student's course grade. We assign homework sets throughout the course, but we do not grade these assignments. Homework serves mainly as practice for the quizzes and course examinations. We link the quizzes with specific student learning outcomes developed for the course. We developed these learning outcomes using Bloom's Taxonomy of Educational Objectives, which define the knowledge, skills, and abilities that students should achieve upon completion of the course. The paper includes example quizzes and student learning outcomes. In the paper, we discuss criteria we follow in developing well-posed and appropriate quiz problems. In addition, we discuss the use of quiz scores in formative and summative assessments. We believe the daily quiz approach provides a valuable and efficient means for assessing student performance. We present assessment results showing correlations between student quiz performance, midterm exam performance, final exam performance, and overall course performance. Finally, we discuss student opinions regarding this approach to course instruction and assessment, and we reflect on the benefits of using this approach in our classes.

Introduction

The following paper describes our experiences using daily quizzes to assess student performance in a third-year civil engineering course on geotechnical engineering. The lead author has assigned daily quizzes in this course for over 10 years. The paper's co-author recently began teaching this course using a similar approach. Daily quizzes offer an excellent opportunity to collect formative assessments of student learning, which provide helpful information to the instructor. In the paper, we summarize quiz results and experiences associated with twelve sections of the course taught since 2010. We provide background information regarding course design and format. We also discuss the criteria followed in developing well-posed and appropriate quiz problems, and we present assessment results associated with over 6,000 quizzes administered over the past five years.

Background

Instructors teach the subject introductory geotechnical engineering course in the third year of an undergraduate civil engineering curriculum. At California Polytechnic State University, San Luis

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Obispo (Cal Poly), the academic year consists of four quarters, each eleven weeks long. Course instruction takes place over a ten-week period with final examinations administered during the eleventh week of the term. The subject course is a 4-unit lecture course, which means it meets in a classroom for four hours each week. Typically, the university adopts a two-day schedule for 4-unit course offerings, meaning the course meets for two hours each day following a Monday-Wednesday or Tuesday-Thursday calendar.

Bachelor of Science degree curricula for both the civil and environmental engineering majors require the geotechnical engineering course. Approximately 35 students enroll in a single course section, and the ratio of civil to environmental engineering students is typically four to one. Our civil engineering majors must enroll concurrently in a 3-hour geotechnical engineering laboratory course that meets once per week during the term. Experiments performed during this laboratory (typically six to eight in total) serve to complement the material covered in the subject "lecture" course.

We divided the geotechnical course into ten primary topics or "learning modules," which focus on the topics listed in Table 1. We present terminology, definitions, concepts, theories, problem-solving techniques, and other information related to these topics using in-class lessons, supplemental notes, and textbook readings. The in-class lessons involve considerable work on the chalkboard (or white-board) and include frequent student questioning[1]. The supplemental notes include learning outcomes, additional details on important concepts, problem solving tips, and examples. We assign textbook readings to support the notes and in-class lessons. The textbook is the second edition of *An Introduction to Geotechnical Engineering* by Holtz et al.[2]

Table 1 - Essential Course Topics or Learning Modules

Topic Number	Learning Module Focus
1	Introduction to Geotechnical Engineering
2	Terminology, Definitions, and Phase Relations
3	Geotechnical Site Characterization
4	Index Properties and Classification Tests
5	Soil Classification
6	Earth Moving and Soil Compaction
7	Geostatic Stress Calculations and Earth Pressures
8	Hydraulic Conductivity and Darcy's Law
9	Two-Dimensional Flow and Flow Nets
10	Soil Stiffness and Strength

Formal assignments for the course include homework, quizzes, and examinations. We developed separate homework assignments for the learning modules, each containing 10 to 15 problems. We do not collect or grade these assignments. Rather, we evaluate student performance using daily quizzes and two examinations (a midterm and a final). During the last

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offering of the course, the grading breakdown was as follows: quizzes (40 percent); midterm (30 percent); and final (30 percent). We administered 17 quizzes during the term. A course at Cal Poly that meets twice per week will typically have 20 scheduled class meetings. Excluding the first and last class meetings, the midterm exam meeting, and any holidays, a maximum of 17 class meetings are typically available for in-class quiz administration.

We prefer assigning daily quizzes for this course because: (1) regular assessment motivates the students to keep up with the course schedule, learning modules, and homework assignments; (2) the quiz problems provide additional practice opportunities for the students, which improves student learning and retention[3]; (3) performance on the quizzes allows the instructors to regularly assess individual student progress and understanding; and (4) rapid formal assessment helps the instructors to modify and/or supplement concurrent lessons in response to shortcomings in student performance. Furthermore, quizzes, unlike homework, guarantee an assessment of individual student learning. Based on our experience, some students will collaborate on homework assignments even when instructed not to. Developing the skills necessary for effective teamwork and collaboration is most certainly important for our students; however, we do not focus on these skills as part of this course.

Learning Outcomes

Course learning outcomes define what the students should know and be able to do upon completion of a course topic[4]. Previously, the lead author identified essential knowledge and skills for each of the course topics listed in Table 1. He then developed three to seven matching learning outcomes for each course topic[5]. The supplemental notes for each learning module include a list of these learning outcomes. We regularly refer to these learning outcomes throughout the course to orient the students to important concepts.

As an example, Tables 2 and 3 list the learning outcomes defined for two of the topics listed in Table 1. Bloom's original taxonomy of skills for the cognitive domain included six levels of student understanding of a concept or topic, ranging from 'knowledge' at the lowest level to 'evaluation' at the highest level[6]. Anderson et al. revised Bloom's taxonomy by proposing a framework with 'Knowledge' and 'Cognitive Process' dimensions[7]. The latter dimension closely resembles the original taxonomy: it represents a continuum of increasing cognitive complexity with six categories (or levels) spanning lower-order to higher-order thinking skills. In revising the original taxonomy, Anderson et al. proposed the following six levels: (1) remember; (2) understand; (3) apply; (4) analyze; (5) evaluate; and (6) create. The revised version of the taxonomy reflects advances in educational research since Bloom's original work and provides a more relevant tool for instructors developing curricula and assessing student performance. We used the revised taxonomy when developing learning outcomes. Tables 2 and 3 identify an action verb for each outcome along with an estimate of the level of achievement in the cognitive domain. A separate paper discusses the development of learning outcomes for this course[5].

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Table 2 - Learning Outcomes for "Terminology, Definitions, and Phase Relations"

Action Verb	Outcome (# of Achievement Level in Cognitive Domain)
Define…	important volume ratios, mass ratios, and densities. (1)
Prepare…	a properly formatted phase diagram for a given soil sample. (3)
Calculate…	void ratio, degree of saturation, water content, density, and unit weight from a given set of soil sample data. (3)

Table 3 - Learning Outcomes for "Soil Classification"

Action Verb	Outcome (# of Achievement Level in Cognitive Domain)
Scrutinize…	sieve analysis and Atterberg limits test results for the purpose of soil classification. (4)
Classify…	a soil according to the Unified Soil Classification System (USCS) by providing a group symbol and group name. (3)
Predict…	the engineering behavior of soils (relative to compressibility, strength, and hydraulic characteristics) based on classification results. (5)
Explain…	how the structure and fabric of fine-grained soil differs from that of coarse-grained or granular soil. (2)

Daily Quizzes for Assessment

We use a variety of formative assessments during the term to gauge student learning. Techniques include student questioning, in-class collaborative learning exercises, and quizzes. Regular (daily) quizzes represent the primary formative assessment tool used by the authors to quantitatively measure student learning. We typically administer these quizzes during the final 5 to 10 minutes of a class period. We link the quizzes to specific learning outcomes already addressed in class lessons and/or textbook readings. We score each quiz using a 5-point scale and a pre-defined grading rubric. Experience has shown that an instructor can typically grade a set of quizzes for a 35-person class in about 45 to 90 minutes, depending on the learning outcome addressed in the quiz problem. Included below is an example quiz question, which links with the third outcome in Table 2.

> *Approximately 50 cubic yards of clayey soil are excavated for a utility trench. The water content and dry unit weight of this soil are 19 percent and 100 pounds per cubic foot (pcf), respectively. This soil will be used to backfill the trench after the utility pipe is placed. Before the soil is placed into the trench and compacted, it must be moisture conditioned (i.e. water must be added to it). The new water content of the soil must be approximately 26 percent before placement. To meet this condition, how much water*

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must be added to the originally excavated soil? Report your answer in cubic feet (ft^3) and gallons.

We purposely designed the quizzes to be short so that: (1) a limited amount of class time is used; (2) the problems are relatively easy to grade; and (3) the instructors can quickly turnaround feedback to the students. Prompt grading allows the students to evaluate their own progress relative to different learning outcomes. A quick turnaround of assessment results also helps us to evaluate class progress. A poor quiz grade for the class may indicate the instructor needs to slow down and provide additional review for a particular subject. In addition, progress can be tracked for individual students, thus alerting an instructor to individuals who possibly require some form of intervention (e.g. an encouraging e-mail, an office hour meeting, more detailed written feedback on a quiz, etc.). Overall, we find daily quizzes to be extremely valuable instructional tools as they provide real-time data on student learning.

Examinations for Assessment

The midterm and final examinations constitute the primary summative assessment approaches we use to evaluate student learning. Examinations include multiple-choice, short answer, fill-in-the-blank, and true-false prompts and are written to address both concepts and problem solving. For a typical examination, a student will have approximately 2 hours to complete 25 to 30 questions. Before the examination, as part of a short 5- to 10-minute review session embedded within a scheduled lesson plan, we identify which learning outcomes will be addressed. We then develop the examination with the goal of evenly distributing the questions among the specified learning modules and outcomes.

Summary of Quiz Results

Table 4 summarizes quiz results for twelve offerings of the subject course. The table includes data on class enrollment, number of quizzes administered during each course, number of take-home quizzes administered (if any), total number of quizzes graded during a particular course, and quiz scores. The table also summarizes average examination and course scores for each class. The data are consistent for the five-year tracking period, despite the different course instructors and the high number of course sections taught.

On average, we graded approximately 500 student quizzes during each course offering. If we assume it takes approximately 2-3 minutes to grade an individual quiz, then the time required for quiz grading throughout a term equates to approximately 20 hours. Based on our experience, this time is comparable with or even less than the time required for grading regularly assigned homework sets.

A quiz score of "0" almost always indicates a class absence for a student. Table 4 illustrates we typically recorded a small number of absences each term. In fact, the total number of "0" point quiz scores represents only 3 percent of the total number of quizzes we administered. Overall, the attendance rate observed for this course exceeds that which we typically measure for our other courses where daily quizzes are not assigned.

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A quiz score of "5" represents a perfect score. Table 4 notes the number of "5" point quiz scores recorded for the entire list of course offerings. The total number of "5" point quiz scores represents nearly 40 percent of the total number of quizzes we administered. The average quiz score for all quizzes is 3.96. These scores align with our goal for the students: we hope they perform well on the quizzes. The quizzes should serve as positive reinforcement, and students will do well if they keep up with the course material and focus on the learning outcomes.

Table 4 - Summary of Quiz, Midterm, Final, and Course Scores from 2010 to 2014

Class ID	No. of Students	No. of Quizzes	Take-Home Quizzes	Class Quiz Totals	Quiz Score "0"	Quiz Score "5"	Ave. Quiz Score Out of 5 and (%)	Midterm Exam Score* (%)	Final Exam Score (%)	Course Score (%)
2010_4	47	14	0	658	10	232	3.90 (78.0)	72.6	66.9	73.3
2011_2	25	16	2	400	24	142	3.65 (73.0)	80.8	75.9	77.6
2011_4a	36	19	2	684	14	212	3.80 (76.0)	79.9	73.1	78.8
2011_4b	38	19	2	722	38	260	3.86 (77.2)	79.8	78.7	80.7
2012_1	27	15	2	405	1	182	4.20 (84.0)	83.1	67.4	79.8
2012_3	14	17	0	238	3	95	4.10 (82.0)	---	79.2	82.6
2012_4a	33	17	1	561	18	222	4.00 (80.0)	80.3	77.4	80.4
2012_4b	21	17	1	357	10	140	4.04 (80.8)	79.4	82.9	82.4
2013_1	42	16	2	672	7	300	4.16 (83.2)	77.3	76.4	81.0
2014_1	37	18	3	666	6	288	4.16 (83.2)	80.5	74.3	81.2
2014_3	11	20	2	220	4	110	4.04 (80.8)	---	69.4	78.7
2014_4	38	17	0	646	52	272	3.66 (73.2)	78.1	76.5	78.9
Total or Average:	369	205	15	6229	187	2455	3.96 (79.2)	79.2	74.8	79.6

* - Midterm examinations not administered during two summer course offerings

Table 4 illustrates that average quiz score (for all of the quizzes we administered) is essentially equal to the average course score for all of the students enrolled in the subject course. On Figures 1 and 2, we compare individual student performance for quizzes and the examinations. The graphs on these figures show individual quiz score versus individual examination score for 369 total students. As evident, student quiz performance typically exceeds examination performance, on average. The difference between a student's quiz and examination scores is more evident for the final examination data.

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On Figure 3, we compare individual student performance for quizzes and the final course score. As evident, a student's quiz score correlates more closely with his or her final course score, in comparison with the examination data presented on Figures 1 and 2.

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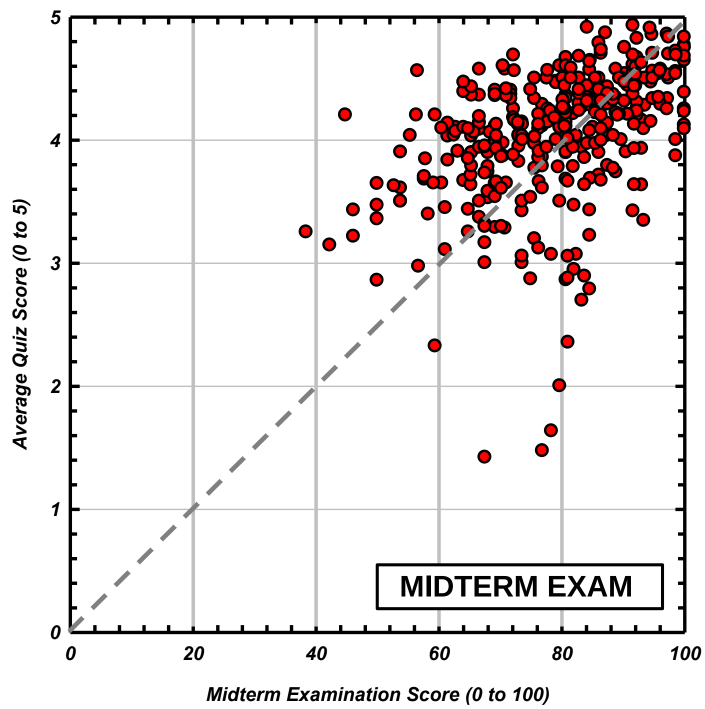

Figure 1 - Comparison of Individual Quiz and Midterm Exam Scores (369 students enrolled in classes listed in Table 4)

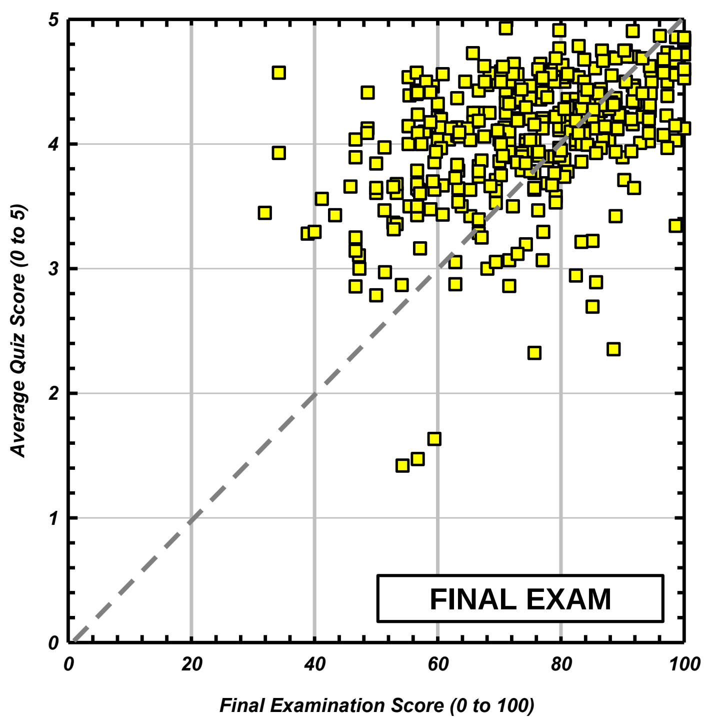

Figure 2 - Comparison of Individual Quiz and Final Exam Scores (369 students enrolled in classes listed in Table 4)

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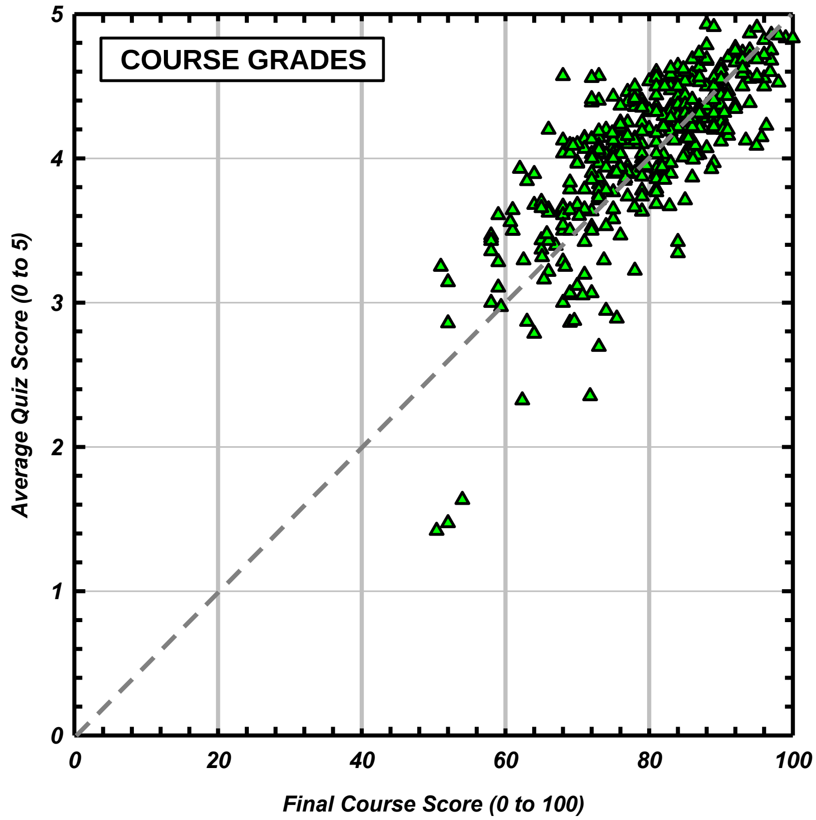

Figure 3 - Comparison of Individual Quiz and Course Scores (369 students enrolled in classes listed in Table 4)

Student Comments

Students at Cal Poly assess instructor effectiveness by completing a Student Opinion Form during the last week of the term, but before administration of the final examination. Multiple-choice questions on this form relate directly to course design and teacher performance. Students also have the option to include written comments. Student responses are anonymous. Instructors receive these responses only after posting final grades.

Overall, student feedback for the subject geotechnical course has been very good. The students typically comment positively about the high level of course organization; the fairness of the quizzes and midterm problems; and the usefulness of the supplemental note packet. All relate directly to the development and presentation of clearly defined learning outcomes. Written feedback corroborates our above opinions and instructor ratings (which are typically high). Below are selected student comments for the course offerings summarized in Table 4. We sampled only those comments related directly to the daily quiz aspect of the course.

"Quizzes became a bit tiring, but overall a great class and great instructor. I learned a lot and this has been one of my favorite CE classes. Thanks a lot!"

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"Frequent quizzes gave a lot of feedback and were more manageable than collected homework problems."

"Daily quizzes instead of homework works well. Good motivation to go to class."

"Extremely fair quizzes, midterm, and grading. Expects the students to know a lot."

"Overall a well-rounded and fair class. Some quiz and test material (problems) were not covered in class."

"Quizzes and homework were a little more difficult than the material presented in class."

"Excellent teacher. Quizzes/tests were challenging, but fair."

"Like the layout of the class. Notes and syllabus were good. Quizzes every class were annoying, but overall helped me to keep up with the material."

"Quizzes are a good idea and have made it easy to keep up and learn material."

"Daily quizzes helped me keep up with the class."

"Grading is designed in a way that measures attendance rather than intelligence."

"Perhaps have one quiz a week rather than one every day."

"Quizzes keep you on your game – wish I had tried harder earlier on."

"As much as I hated having daily quizzes, it kept me on top of the material."

"Even if I did poorly on the quizzes, I still felt like I've learned a lot."

"The amount and frequency of quizzes was very helpful. Keeps us on our feet and are very representative of the midterm questions."

"I liked the structure of the class. Quizzes were fair."

"Quiz percentage was a little high compared to midterm/final, especially when we study for the tests so much more than the quizzes."

"Quizzes were a great review, but I sure hope they are curved."

"In the beginning I didn't like having a quiz every class but by the end I was used to it. I think I would still rather have homework due once a week, and then a quiz the other day."

"Very good professor. Would be nice to have homework as a cushion for the grade though."

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The comments illustrate that course workload and "required" attendance are sometimes sources of frustration. Each quarter, some students will bemoan the daily quiz requirement in their written instructor reviews. However, we believe the value of daily quizzes as a formative assessment tool outweighs potential negatives (i.e. increased instructor workload, reduced class time available for lessons, frustrated students, etc.). To help reduce student frustration and potential anxiety, we typically drop the lowest quiz score for each student prior to computation of final grades. In addition, we sometimes allow the students to complete a quiz assignment as homework, and we may occasionally offer a bonus quiz as a score-boosting opportunity.

Reflection

Daily quizzes designed to target specific learning outcomes have proven to be a useful instructional tool. They encourage our students to avoid procrastination and help them to be successful during the relatively fast-paced 10-week quarter. Promptly graded quizzes provide each student (and the instructor) with feedback in real-time. As a result, concurrent lessons may be adjusted to address shortcomings in student learning and teacher performance. By providing an opportunity for class success each day, students can incrementally improve.

Daily quizzes offer a new instructional format for many students. Helping students to overcome potential frustration and anxiety can be challenging for an instructor, and developing teacher-student rapport proves even more important in these cases. Furthermore, prompt grading of the volume of quizzes generated each class meeting potentially adds workload for the instructor. Instructors must gauge for themselves whether this workload is worth it. We believe it is.

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Two Digital Design Courses with Complete Public Domain Courseware Support

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Abstract

Courseware is a major component in the cost of engineering education. Two aspects of this cost include frequent new editions of textbooks and the long path those textbooks travel from author to students. Authors can mitigate these issues by creating and making available "free knowledge". This paper describes the "FreeRange" series, which is a complete set of public domain courseware that supports two digital design courses. The first course introduces basic digital design while the second course covers computer design and assembly language programming. Both courses are unique in that they present their subject matter with primarily a modular systems-level approach. Moreover, these courses emphasize high-level design concepts while removing some lower-level topics typically associated with digital design. The FreeRange digital design course support includes the basic text, a VHDL tutorial, and a lab manual. The courseware associated with the computer design course includes the basic text, a lab manual, an assembler manual, and an assembler/debugger. The computer design course guides students through the development of the RAT microcontroller, which is an 8-bit microcontroller that students model and synthesize on an FPGA-based development board. Applying a high-level modular design approach enables students to model the RISC-based RAT microcontroller architecture in a ten-week course. Students then use their synthesized microcontroller to test assembly language programs on actual working hardware. The assembler/debugger allows students to assemble their programs and observe how instruction execution affects the underlying hardware. The entire "FreeRange" courseware series includes approximately 1600 pages of self-published material.

Motivation

A major obstacle to obtaining success in higher-level education is the monetary cost of that education. While society generally touts the benefits of higher education, students remain on the bottom of a food chain that seems overly willing to increase the basic cost of that education. Many people view this system as a problem as the cost of education has social as well as economic impacts on students and potential students[1]. We can mitigate some aspects of this problem by making courseware available at no cost.

One advantage of creating free courseware is that all aspects of the work are controlled by one source. This removes various profit-generating entities from the book's path from author to

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student and effectively protects students from textbook prices that are rising faster than the overall inflation rate[2]. The FreeRange courseware bypasses the common notion that publishing companies generate new versions of texts in order to obsolesce cheaper used versions of the texts. Another advantage of having single source control over the courseware involves the presentation of the subject matter and its relation to the relatively fast advances in digital technology. Though the topics associated with basic digital courses do not change, there have been significant changes in the implementation of the associated circuits. The emergence of PLD-based development boards has freed students from the constraints of hand-wiring circuits using discrete logic and breadboards.

Paper Overview

This paper describes our approach to digital design in the FreeRange courseware. The FreeRange courseware consists of texts and software associated with a basic digital design course and a computer design/assembly language programming course. The courseware includes two basic texts, two lab manuals, an assembler manual, and an assembler/simulator. The texts and lab manuals utilize VHDL to model circuits. The courseware emphasizes a relatively high-level modular approach to digital design while removing or de-emphasizing other aspects of digital design. The computer design text uses this modular approach to describe the basic operation and implementation of a fully-operational microcontroller.

FreeRange VHDL

FreeRange VHDL provides an introduction to the concepts of modeling digital circuits with a Hardware Description Language (HDL). The main goal of this text is to present VHDL modeling in such a way as to make them immediately useable for actual modeling. While most VHDL texts present every aspect of various subjects, FreeRange VHDL presents only the material students need to know in order to start modeling circuits. FreeRange VHDL assumes the reader is familiar with basic digital design and provides little explanation of digital terms and concepts. FreeRange VHDL describes basic digital circuits such as MUXes, decoders, flip-flops, and the behavioral modeling of finite state machines (FSMs). Initial versions of this text still exist on the internet under the names “Low-Carb VHDL” and “Shock & Awe VHDL”. Fabrizio Tapidero, the co-author of FreeRange VHDL, vastly improved the presentation of the previous versions.

FreeRange Digital Design (FRDD)

FRDD provides an introduction to basic digital design concepts and VHDL modeling. This text was designed to support a previously described digital design course[3]. FRDD is unique in that it focuses on modern digital design using VHDL while not including some topics found in typical digital design texts. The overall theme of FRDD is that digital design is analogous to structured programming in that digital designers can implement even the most complex digital circuits using a combination of basic digital circuits. Figure 1 shows a diagram of FRDD’s basic digital design modules and their relation to digital logic design. FRDD does not emphasize the following topics:

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- In-depth notions of transistors
- Function reduction using digital theorems
- In-depth function reduction using Karnaugh Maps
- References to discrete hardware devices
- Uncommon number representations

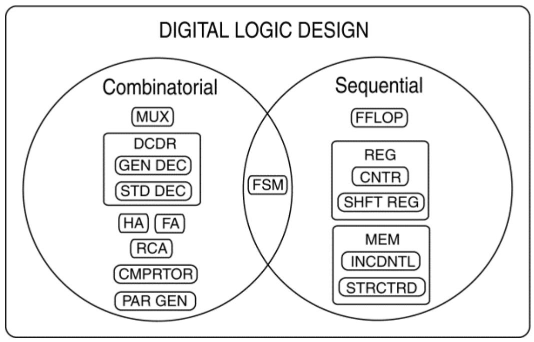

Figure 1: FRDD's view of basic digital design modules.

The design approach in FRDD is unique in that it divides all digital design into the following three categories:

1) Iterative or Brute Force Design (BFD)
2) Iterative Modular Design (IMD)
3) Modular Design (MD)

The heart of BFD is the truth table; FRDD uses the BFD approach to design half-adders (HAs) and full-adders (FAs), and later to design other relatively simple circuits. Students use Karnaugh maps to reduce the Boolean equations associated with their designs, but the use of Karnaugh maps limits the complexity circuits designed using the BFD approach. IMD also has basic limitations in that it is only applicable to a small set of standard digital circuits including ripple carry adders (RCA), comparators, and parity generators/checkers. The heart of IMD is a basic module that the circuits uses iteratively to increase the functional width of the circuit. FRDD primarily uses the MD approach, which it emphasizes by introducing multiplexors and decoders in order to allow students to complete non-trivial, though purely combinatorial designs. The main theme of these designs are arithmetic circuits, which students are able to design because FRDD covers basic number systems and signed/unsigned binary number representations.

Mixed logic design is the final topic included in combinatorial section of FRDD. The text covers this topic because other digital design texts generally do not present this topic in an understandable format. Because the topic of mixed logic is somewhat non-intuitive, FRDD presents this topic using a unique and understandable approach. FRDD presents mixed logic

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concepts using the notion of equivalent gates and equivalent signals in a context of direct polarity indicators (DPI).

Finite state machine (FSM) design is the main theme of the sequential circuit portion of FRDD. FRDD uses an intuitive approach to FSMs by first describing the low-level FSM design/analysis and then moving onto more practical FSM designs that implement counters and sequence detectors. While these circuits are instructive, the text considers the basic notion of a FSM as a circuit that controls other circuits. FRDD emphasizes the difference between Mealy and Moore-type FSMs including their flip-flop-based implementations. This approach uses timing diagrams to highlight the functional differences between FSMs types and also includes related topics such as self-correcting FSMs, hang-states, setup/ hold times, and maximum system clock frequencies. FRDD places special emphasis on state diagram representations of FSMs because state diagrams are common in many engineering fields and computer science. The text emphasizes that the engineering step in FSM design is developing the state diagram; FRDD uses VHDL behavioral modeling to model the FSMs.

FRDD also includes coverage of the various flavors of registers, their modeling using VHDL, and their basic usage in digital circuits. This coverage includes registers with features such as parallel resets and loading, shift registers (simple and universal), and various flavors of counters. FRDD emphasizes the use of VHDL to model counters because VHDL facilitates the relatively straight-forward implementation of standard counter features.

FreeRange Digital Design Lab Activity Manual (FRDD LAM)

FRDD was originally designed to support a basic digital design course, which included a laboratory component. The resulting lab activity manual has two parts: 1) an overview of basic lab and lab reporting procedures and, 2) the lab activities themselves. The non-lab activity portion includes VHDL style files, various lab reporting procedures, and issues associated with the PLD development environment.

The lab activities portion of the LAM currently includes 27 experiments. These experiments are relatively short but increase in complexity as the course proceeds. Students model their circuits using VHDL and then test their synthesized designs on an FPGA-based development board. The background information associated with each experiment is relatively short in an effort to encourage students to find the information in the FRDD text or to ask questions of the course instructors. Each experiment also includes questions that students are able to answer if they understand the topics of the experiment.

FreeRange Computer Design (FRCD)

FRCD supports a ten-week course titled: “Computer Design and Assembly Language Programming”. The text design and support courseware thus needs to present two non-trivial subjects in a relatively short time span, which presents some issues. The primary issue is that no existing text currently supports the presentation of this course material in a relatively short

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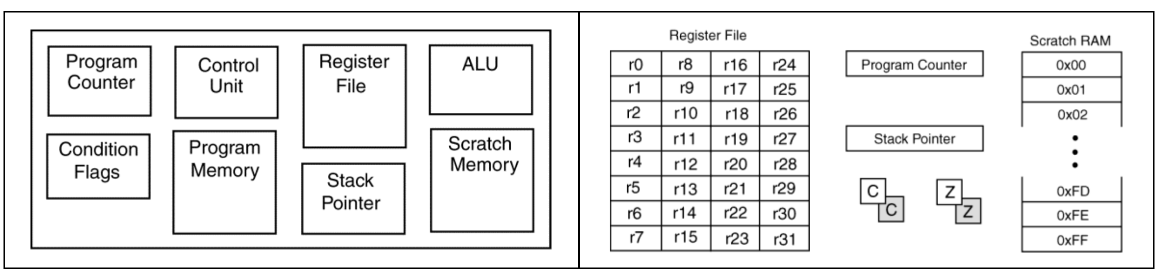
period. Moreover, existing texts with related course material are expensive and the associated hardware is too complex to implement in a ten-week period. We designed FRCD and the associated courseware to successfully handle these issues. The idea for this course originated with a previously described work[4].

The theme of the resulting courseware is the implementation of the RAT Microcontroller (MCU). The RAT MCU is simple enough such that students can model it in a relatively short time but also complex enough to provide students with a meaningful learning experience in both computer architecture and assembly language programming. The RAT MCU continues the modular design experience by presenting an MCU that students model as a collection of standard digital circuits controlled by a FSM. FRCD takes the approach of initially presenting the final RAT MCU architecture to students and expecting them to understand and implement all aspects of the architecture. Students implement the RAT MCU instruction set during the course and then use it to learn the major aspects of assembly language programming. The courseware guides students through modeling the RAT MCU and programming the eventual synthesized MCU on an FPGA-based development board. The RAT MCU has the following features:

- 8-bit RISC architecture with 48 instructions
- Two condition flags
- Programmed I/O with one interrupt
- 32 general purpose registers
- 1024 location instruction memory
- 256 location scratch memory

The RAT MCU architecture is relatively simple yet the synthesized MCU can implement relatively complex assembly language programs. We keep the RAT MCU architecture modules close to standard digital modules and emphasize the interconnection of those modules and their subsequent control by a FSM (control unit). Figure 2(a) shows the RAT MCU's main modules and Figure 2 (b) shows the associated programmer's model.



(a) (b)

Figure 2: RAT MCU main modules (a) and programmer's model (b).

FRCD is responsible for presenting various aspects of computer design and assembly language programming as well as the RAT MCU architecture. FRCD contains four distinct sections:

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1) Introduction to computer architecture and assembly language programming concepts
2) Introduction to basic computer-related hardware modules
3) Software aspects of programming the RAT MCU
4) Hardware aspects of modeling the RAT MCU

The first section introduces the course topics and also provides a review of the standard digital modules described in FRDD. The goal of this section is to place basic computer design in the context of previously acquired digital design skills and knowledge. The second section provides a more direct hardware foundation to prepare students for the modules and techniques they use when implementing a basic computer. This section includes a discussion of basic registers, special registers such as shift registers and counters, and tri-state outputs. The information on registers also appears in the FRDD text, but FRCD augments this approach by introducing the concept of register transfer language (RTL) as a means of representing basic computer-type operations.

The second section also introduces the notions of various types of computer memory, which it supports by penning the names "incidental" and "structured" memory. FRCD considers modules such as flip-flops and registers as incidental memory while referring to larger memory devices such as RAM and ROM as "structured" memory. This distinction helps differentiate the various types of memory in the RAT MCU. This section uses VHDL models to introduce the basic notions of RAM and ROM, including RAMs with bi-directional connections. FRCD introduces arithmetic logic units (ALUs) using both low-level hardware and VHDL behavioral modeling. The lab portion of the course expects students to model the RAT MCU's ALU using VHDL behavioral modeling and making use of VHDL arithmetic libraries.

The third section of FRCD provides a pure programmer's perspective to the RAT MCU, which is intentionally independent of all hardware aspects of the RAT MCU. This section starts with high-level overview of assembly language and the RAT MCU instruction set and continues with descriptions of the assembler and basic assembly language program formats. FRCD presents assembly language programs as a set of basic "tricks" that programmers use often to achieve their programming goals. This approach makes learning assembly language primarily about learning how to use basic programming constructs at the assembly language level. This being the case, the third section uses simple examples to introduce basic programming constructs simultaneously with the introduction of the various RAT MCU instructions. Other tricks include the notions of bit banging, bit masking, number comparisons, and look-up table (LUT) implementations. The third section also presents over forty solved and explained assembly language programming examples of varying complexity.

The final section of FRCD describes the underlying RAT MCU architecture. This description includes subsections of each RAT MCU module including the control unit, program counter, register file, scratch RAM, and condition flags. The section also includes descriptions of the interrupt and I/O architectures including associated timing diagrams. Because students must implement the RAT MCU on a development board, the final section also includes a description

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of the associated “wrapper”, which is a VHDL module that provides an interface between the RAT MCU and the development board.

A basic tenet of the FreeRange approach to computer architecture is that the RAT MCU architecture is nothing special. This means we emphasize that many of the design decisions associated with the RAT MCU architecture and instruction set architecture (ISA) were arbitrary. Thus if students understand all aspects of the architecture and instruction set, they can describe required changes for various architecture modifications. This final section thus contains many examples describing changes required to perform such things as including different instructions, adding additional hardware modules, or modifying existing modules.

FreeRange Computer Design Lab Activity Manual (FRCD LAM)

The FRCD LAM primarily drives the incremental development of the RAT MCU. This manual currently contains eleven experiments and one “final project” description. The basic outline of the LAM is as follows:

- Two FSM-based experiments
- One disassembly experiment
- Three experiments for RAT modules: program counter, memories, ALU
- Three experiments incrementally assembly complete RAT MCU
- Two experiment involving interrupts

The first two experiments use FSMs to control external hardware that perform relatively basic operations involving RAMs. These experiments emphasize the notion that a computer is simply a FSM controlling standard digital modules. The next experiment emphasizes the underlying RAT MCU instruction formats by having students disassemble machine code. The next three experiments involve the design of the RAT MCU’s program counter, memories (register file and scratch RAM), and ALU. The following three experiments incrementally assemble the RAT MCU into a working computer in three stages: 1) a working computer with five instructions, 2) a working computer with no interrupt capability, and, 3) the completed RAT MCU. The final two experiments involve the use of interrupts and interfacing with an external timer module. The final laboratory experience requires students to use their RAT MCUs to implement a project of their choosing in order to learn assembly language programming practices associated with relatively large programs. The main requirement of the project is to interface the RAT MCU with at least one of several peripherals including a UART, a keyboard, a mouse, or an external device of their choosing.

RAT MCU Assembler Manual

The RAT MCU Assembler Manual contains all the information about the RAT MCU assembler and instruction set. The RAT MCU assembler is part of the RAT MCU Assembler/Debugger software. The major topic in this manual are the following:

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- Description of assembler directives
- Description of code and data segments
- Description of various instruction formats
- Detailed description of each instruction

The RAT MCU assembler uses directives similar to those found in other assemblers. The assembler also includes a .DB directive, which allows programmers to initialize data memory. The assembler facilitates data initialization by automatically inserting start-up code into programs, which allows programmers to define look-up tables in data memory.

The assembly manual describes the RAT MCU's five distinct instruction formats for its 48 instructions. Table 1 shows the five instruction types with examples. The manual also contains a detailed description of each instruction, which includes RTL equations, written descriptions, instruction word formats, effects on condition flags, and basic usage examples.

Description	**Example**
Register-Register	`ADD    r0,r1`
Register-Immediate	`ADD    r2,0x56`
Register	`PUSH   r5`
Immediate	`CALL   My_sub`
None	`RET`

Table 1: RAT MCU instruction types and examples.

The RAT MCU Simulator/Debugger

The RAT MCU Simulator/Debugger is a Windows-based application that allows students to assemble, simulate, and debug RAT MCU assembly language programs. The "Debugulator", designed by former students Tim Peters and Doug Gallatin, performs the following functions:

1. Source code editor
2. Assembler
3. Generates program memory VHDL model
4. Simulator/Debugger

The Debugulator invokes the RAT MCU assembler, which is a different piece of software than the Debugulator. We wrote the assembler for beginning assembly language programmers as it performs extensive error checking. The assembler also outputs a VHDL ROM model containing the machine code associated with a given program. The Debugulator contains a feature-set typical of other assembly-level debuggers including the ability to run programs, set breakpoints, step through programs, and simulate interrupts. The Debugulator shows the current state of the

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processor including panes for register file and scratch RAM values, and input/output port addresses; users can change these value by entering new values.

Conclusion

The FreeRange courseware represents many years of work, 95% of which was done by a single person. Though this courseware has saved Cal Poly San Luis Obispo students an estimated $500k through the past eight years, many issues remain. The main issue is that the courseware could use improvements including more proof-reading, more example and exercise problems, and improved lab activity experiences. A secondary issue is that the scope of the FreeRange courseware has never been acknowledged in any way by the Cal Poly administration. Though the FreeRange courseware is relatively popular with students and faculty who teach the courses, it is essentially a career-killer in the context of an administration that places a higher value on research, publications, and grant acquisitions than it does on actual course development.

Acknowledgements

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Latest versions of the FreeRange courseware live at: http://www.ee.calpoly.edu/faculty/bmealy/

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Utilizing Wolfram Alpha in Teaching Mathematics

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Abstract

Computer Algebra Systems such as Maple and Mathematica can greatly improve student's understanding of traditionally complex topics in mathematics and engineering. Such systems can handle complex computations and return results immediately providing students with instant feedback. The systems can facilitate an interactive learning session in which students can rapidly formulate solutions, test ideas and verify their calculations. In 2008 Wolfram Research unveiled Wolfram Alpha, an online publicly available knowledge base computational engine based on Mathematica. Wolfram alpha constructs response to queries by performing real time dynamic computations on its extensive repository of built in data, algorithms and methods. The system can receive a free form input query in plain English and dynamically compute and display results. The system's repository holds data and facts from diverse fields of science, engineering, business and social sciences that provide fertile grounds to construct interesting problems for classroom discussions.

In this paper we examine Wolfram Alpha's features, computational capabilities as well as the demo projects to evaluate the system's potentials as a teaching tool in science and mathematics courses. A broad collection of typical problems in mathematics and physical science courses are tested in the system and the benefits as well as the shortcomings of the system as a teaching resource are discussed.

1. Introduction:

Wolfram Alpha is a computational knowledge engine that is implemented based on the Mathematica Symbolic Algebra System. Wolfram Alpha's built-in knowledge and computational capabilities and algorithms are implemented in Mathematica. The system is capable of receiving input in a form of text, image or tabulated data then compute and display answers along with additional information the system may consider relevant and perhaps useful. The data in the wolfram alpha is organized in such way that the system can efficiently perform dynamic computation and respond to queries. In this paper we examine some features of Wolfram Alpha for teaching college algebra and calculus topics; we will investigate limitations of the system and possible approaches for utilizing the system. In section 2, we'll illustrate how Wolfram can be utilized in teaching college Algebra topics. Section 3 is devoted to some of the standard topics

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students see in first year calculus course. Section 4 briefly discuss additional features of Wolfram and that can be useful in teaching and learning.

2. Teaching Algebra with Wolfram

In this section, we'll illustrate how Wolfram can be utilized in teaching college Algebra topics such as graphing linear equations and inequalities, finding solutions for quadratic equations, systems of equations, and inequalities, and solving problems related to polynomials.

2.1 Graphing Equations and Inequalities

One way to analyze and understand equations and inequalities is to graph them. Graphs can also be utilized to solve equations and inequalities. Wolfram is quite convenient when it comes to producing graphs. The "plot" keyword is understood by Wolfram to generate graphs for linear equations, inequalities, parabolas, polynomials, etc. For example, the command **plot y = x** instructs Wolframs to generate the graph corresponding to the linear equation y = x as shown in Figure 1 below. Users can click on the properties button located on the lower right corner to display the x-intercept, y-intercept, slope, and curvature properties associated with the equation as shown on the right in Figure 1. Note that Wolfram also understands the graph command. Users can request Wolfram to **graph y = x** and Wolfram will still interpret the input as plotting the line. The free format input capability of Wolfram can be more inviting for students to experiment with different related queries and further investigate the concepts.

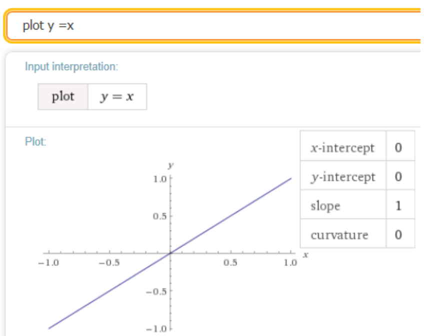

Figure 1 - The plot of y = x and additional tabulated information

A highly useful feature of Wolfram is its ability to generate multiple plots on the same coordinate plane. This feature gives students the ability to easily understand how equations behave and visually compare and describe similarities and differences among equations. To instruct Wolfram to generate multiple plots, users can enter multiple equations. For example, the command **plot y = x + 1, y = 1/2x + 2** will result in the output shown in Figure 2. This example can be used to adequately demonstrate how linear equations react to different slopes and intercepts. Wolfram is capable of plotting up to a maximum of six equations on the same coordinate plane. The system can also be utilized in teaching graph of the basic functions such as polynomials and rational function and study their asymptotic behavior. Wolfram is well suited to show different transformation of graphs since it can show multiple plots on the same coordinate system.

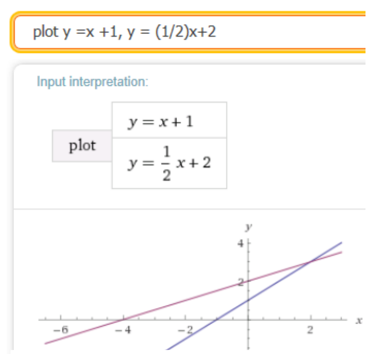

Figure 2 - plot of a linear system of equations

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Often students find equations involving absolute values difficult to comprehend. Wolfram understands absolute values as well. Therefore, Wolfram can be used to sketch graphs involving absolute values. The graphs can then be effectively used to describe the essence of absolute values. This is especially true when the graph for an equation involving absolute values is plotted on the same coordinate plane along with the graph for its corresponding equation without absolute values. For example, as shown in Figure 3 below, the line for y = |x| + 4 is plotted on the same coordinate plane with the line for y = x + 4. However, an obvious shortcoming of Wolfram is that the portion of the graphs where two lines overlap cannot be easily identified (e.g., the lines in quadrant 1 in this example). Users can also use Wolfram to plot inequalities. Figure 3 displays the output from Wolfram plotting the inequality |x| + |y| <= 3. However, in plotting inequalities with "<" or ">", it is found that Wolfram does not correctly identify the boundaries with dashed lines. Figure 4 exhibits the plot generated from Wolfram for the inequality |x| + |y| < 3.

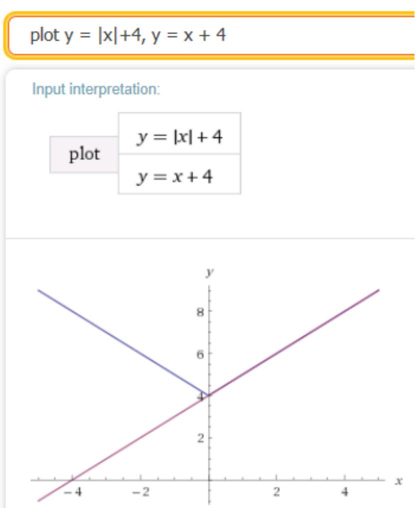

Figure 3 - A plot involving absolute value function

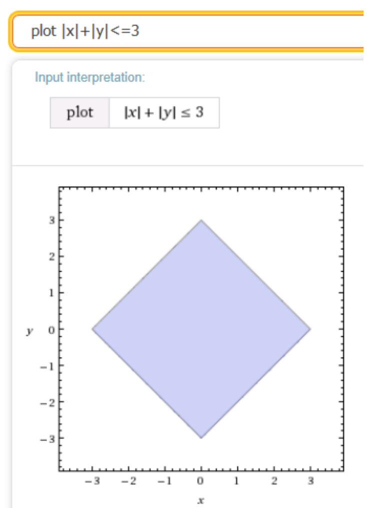

Figure 4 - Plot of an inequality with absolute value

It has been noted earlier that Wolfram can generate multiple plots on the same coordinate plane for up to six equations. However, Wolfram fails to accomplish this when equations involve inequalities.

2.2 Solving Quadratic Equations, Systems of Equations, and Inequalities

The command **solve** tells Wolframs to give solutions to a given equation, for example, quadratic equations, systems of equations, or inequalities. Figure 5 below depicts the usage of the **solve** command to find the solutions to a quadratic equation. With the Wolfram Pro version users have the option to see the "step-by-step" solution, which shows detailed steps leading to the solution, that is, when a closed form solution exists. In instances where no closed form solution exists

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wolfram displays a numerical approximation to the solution and does not produce a step-by-step solution key. In cases where multiple approaches can lead to the final answer Wolfram gives user the option to select a certain method to reach the answer. Figure 6 shows a step-by-step solution given by Wolfram in solving a quadratic equation, it offers two different methods to solve the quadratic equation, either by factoring method or by completing the square, which is essentially the quadratic formula. The step-by-step solution describes each step in the solution and provides an optional hint assist that can further provides clues about the approach. The step-by-step solution feature of Wolfram that is provided in the Pro version of the system can greatly assist in teaching and can also help students master solution steps.

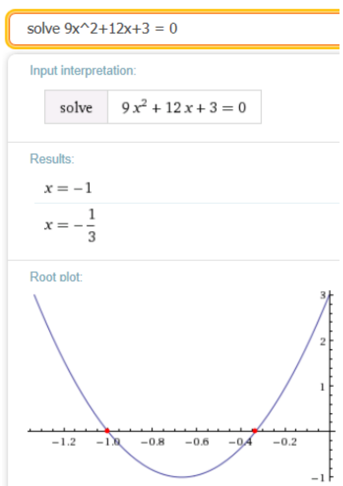

Figure 5- Solving a quadratic equation

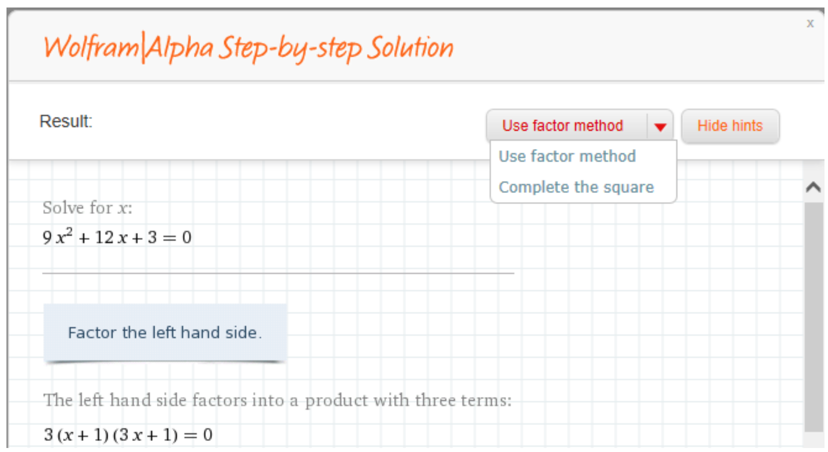

Figure 6 - solution to a quadratic equation along with step by step solution

The input **solve** can be used to solve a large collection of equations including exponential and logarithmic equations that students typically see in college algebra or similar courses and often have difficulty to reproduce solution steps. With Wolfram students can drill through problems and solve as many equations as needed to master steps in solving these problems.

Factoring or simplifying polynomials are among other topics covered in a college algebra course. Wolfram can aid students in this area as well. Students can apply commands such as **factor** or **simplify** to mathematical expression and verify results and review the step-by-step solution. Factoring, dividing and finding roots of polynomials are among routine tasks in introductory algebra classes and all are easily accessible in Wolfram. The free form input in

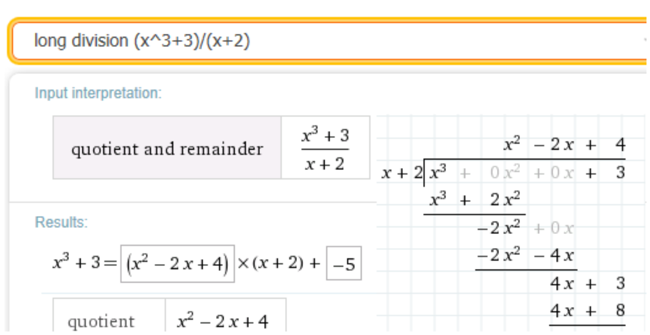

Figure7 - Details of polynomial division

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Wolfram makes it more attractive to students to use since student don't have to necessarily follow a certain syntax to enter their command. With some basic understanding of the concepts and some keywords students can explore and investigate. As an example, in case of polynomial division, inputs with keywords such as **divide**, **long division, quotient,** and **remainder** applied to a rational function will produce the desired result, the system interprets the free form input. In cases where Wolfram may interpret the input in different contexts, the system provides a list of contexts to select from.

3. Teaching Calculus I with Wolfram:

The main topics in the first Calculus course are concepts of limit, continuity, derivative and integration of functions of one variable with applications to curve sketching, related rates problems, optimization and area of the bounded regions on the plan.

3.1 Limits and continuity

A free form input dialog in Wolfram alpha allows for an easy and intuitive computation of limits. To evaluate a limit expression such as $\lim_{x->3} \frac{2x-1}{x+3}$ we can use the basic limit notation and enter the query **limit as x->3 [(2x-1)/(x+3)]** in wolfram's query box. As shown in figure 8, Wolfram displays its interpretation of the query followed by the answer. The system also produces a plot of the function with the value of the limit clearly marked on the graph. Just below the plot is a tab that can make the graph interactive. This interactivity allows a user to trace the graph and follow the x and y components of the points on the graph. This is a useful feature when teaching one sided limits since the abstract action of the limit (on the x and y values) can be demonstrated visually on the graph. The interactivity feature in Wolfram requires a client tool. The Computable Document Format (CDF) client can be freely downloaded from the Mathematica site.

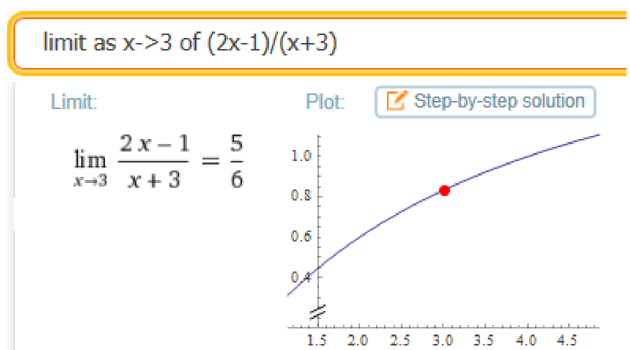

Figure 8- response of Wolfram to a limit query

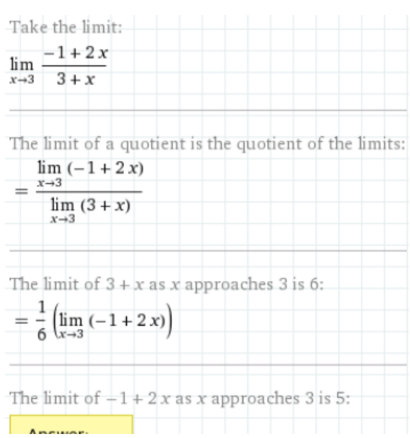

Figure 9- step by step solution to a limit problem

Reviewing the step-by-step solution to the limit problem shows a repeated application of the limit properties to reach

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the final answer. This can help students better understand properties of limits and their application.

To evaluate a one-sided limit a query similar to ***limit (2x-1)/(x+3) as x -> 3 from the right*** can be constructed. The system returns the answer along with the plot of the function. It is also possible to display a tabulated values of the function as the variable x approaches the limit point with the query ***Table [(2x-1)/(x+3), {x, 2.999, 3.001, 0.0003}]***, this table clearly shows how the function values are approaching the limit. Wolfram is capable of piecewise defined functions as input. For example, the one-sided limit $\lim_{x->-1^-} f(x)$ where $f(x)=\begin{cases}2x-1 & \text{if } x<-1\\ x^2+2 & \text{if } x\geq -1\end{cases}$, can be evaluate by the input ***piecewise [{{2x-1, x<-1}, {x^2+2, x>=-1}}] as x -> -1 from left.***

Wolfram system provides a great environment to teach limits since the concept can be applied to variety of functions and instantly obtain the graph of the function and the limit values for classroom discussion. The free form query construction for limits (or any other mathematical operations) encourage students to think about composing their query that can lead to a better understand of the concepts.

A direct application of limits is in investigating continuity of a function at a point. The function $f(x)$ is continuous at a point $x=a$ if $\lim_{x->a} f(x) = f(a)$. This condition can be verified for a given function and a point in Wolfram Alpha. To check for the continuity of a $f(x)=\frac{2x-1}{x+3}$ defined earlier at $x=2$, we can find the limit of the function first then compare this value with the value of the function at $x=2$. We can enter a direct query such as **is (2x-1)/(x+3) continuous at x=2** and get a response, however a better query that checks for the continuity by explicitly using the definition of the continuity might be more reinforcing. This is done by the input ***[limit (2x-1)/(x+3) as x->2] equal [((2x-1)/(x+3), x=2)]*** that will return true. This indicates that the limit value and the function value agree at x = 2, therefore the function is continuous at the point.

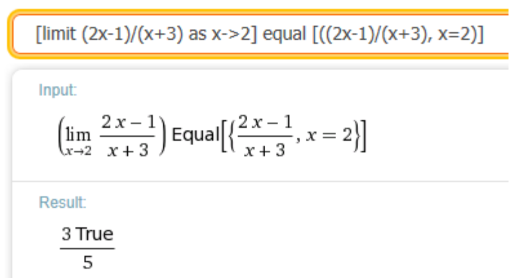

Figure 10- Verify continuity by directly examining the definition

3.2 Derivatives and integration

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To find the derivate of a function such as $f(x) = x^2 + 2x$ we can enter the following limit expression ***limit (((x+h)^2+2(x+h))-(x^2+2x))/h) as h -> 0***, which represent the definition of the derivative involving the limit and difference quotient. Here the difference quotient expression must explicitly be entered into the input box. Unfortunately Wolfram does not allow for defining a function first then using the function in a query such as ***limit ((f(x+h)-f(x))/h) as h -> 0***. It is also possible to symbolically differentiate a function. For example, entering $d(x^2 + 2x)/dx$ in the input box returns the derivative of the function as well, which can be useful to students in verifying their results. Students are often asked to find the equation of the tangent line to a function. This is easily done in wolfram by a query such as ***Tangent line to (x^2+2x) at x = 3.*** The result returns the equation of the tangent line along with the graph of the function. Once again, this could be useful as a teaching tool in relating the derivative to the slope of the tangent line. It is possible to differentiate functions such as using the Leibniz's notation (d/dx), entering the expression **d[(x^3-3)^3/(x^2)]/dx** in the input box produces the derivative. Wolfram applies the quotient rule to produce the final result. To reinforce and practice the rules of differentiation such as the quotient rule, students can explicitly enter the rules in the input box such as **Simplify [[x^2*[(x^3-2)^3]'-(x^3-2)^3*[x^2]']/x^2]**. It is also simple to directly query about some features of a function such as its critical numbers and inflection points and plot the function to confirm the location of its local extremes. Yet, another approach that can aid in learning would be to utilize Wolfram to follow the standard steps in finding these values. As an example, to fine the critical numbers of, say $f(x) = x^4 - 2x^3$, the expression **solve [(x^4-2*x^3)'=0]** produces the critical numbers of the function. One can also enter **critical points of f(x) =x^4-2*x^3** in input box to get the same result. The same ideas apply to finding the inflection points of a function. Wolfram alpha can be a useful tool for students to verify the correctness of their work. Students can be creative as they investigate problems. In case of plotting, students can ask for the local maximum or minimum of a functions and further zoom into the graph by specifying a domain for the plot such as **local minimum of [f(x)=x e^x,(x,-2, 2)]**.

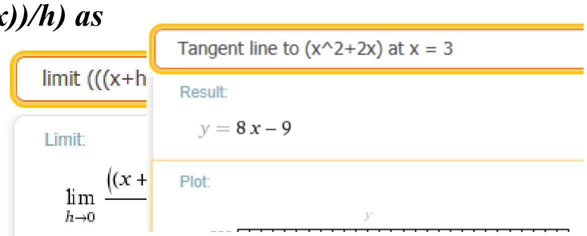

Figure 11 - The definition of derivative

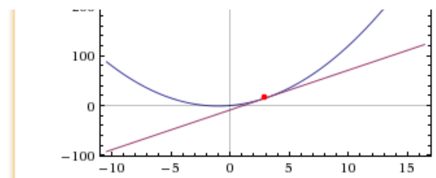

Figure 12 - Equation of the tangent line

Wolfram alpha is also capable of evaluating integrals. The Riemann sum of $f(x) = x^2$ on the interval [0, 5] with 10 subintervals can be queried as **Riemann sum of f(x) = x^2 on [0, 5] with n = 10**. The system will respond with the formulation of the sum, a plot showing approximating rectangles as well as a tabulated result of the approximation using different numerical methods.

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$$\int_0^5 x^2\,dx \approx \frac{1}{2}\sum_{n=0}^{9}\frac{n^2}{4}$$

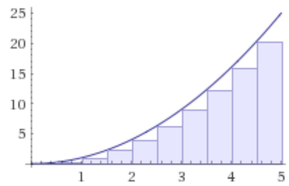

Figure 13(a) - Riemann sum

method	result	absolute error	relative error
left endpoint	35.625	6.04167	0.145
right endpoint	48.125	6.45833	0.155
midpoint	41.5625	0.104167	0.0025
trapezoidal rule	41.875	0.208333	0.005
Simpson's rule	41.6667	0	0
Boole's rule	41.6667	0	0

Figure 13(b) - Riemann sum values

The exact value of the integrals can be obtained by the query **integral of f(x) = x^2 on [0, 5]**.

4. Wolfram Demonstrations projects and Problem Generator

Wolfram site has a large number of publicly available demonstration projects on variety of topics in math and science. In these projects the essential parameters in the problems can be changed while the system recalculates and updates the graph. This clearly help students see the impact of individual parameter changes on the solution. Figure 14 shows a snapshot of the project[2]. The project allow students to change the degree of a polynomial, pick the value of zeros from a preset range and observe the graph of the polynomial. The demonstration projects repository also includes animations where the system animates figures through a present range of parameter values.

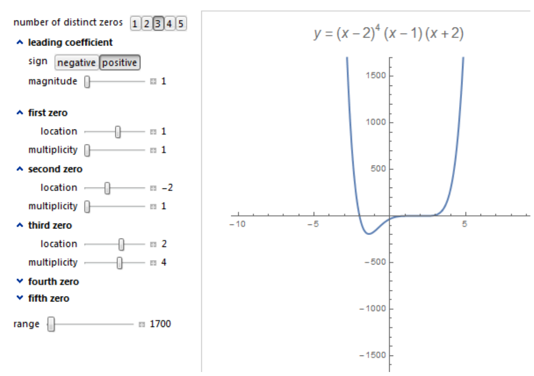

Figure 14 - Graph of polynomials

5. Conclusion

Wolfram alpha can be a great aid in teaching and learning some basic algebra and calculus topics. The free form input in Wolfram free up students from memorizing command syntax and facilitate an environment where students can better explore, investigate, verify and examine implications. The system can be made more useful if compound queries were allowed, in particular, the system should allow user to define a function symbolically then use the function in computation. The system is supplemented with a vast collection of publicly available demonstration projects on variety of topics in mathematics and physical sciences. The projects are animated and aid students in visualizing complex concepts.

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   Demonstrations Project
   Published: June 17, 2014

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Wrapping Your Thread Around the Proverbial Yo-Yo: The Spool Inquiry-Based Learning Activity

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Abstract

Rigid body kinetics, particularly of rolling objects, proves to be one of the most difficult topics for dynamics students to understand. There are complex relationships between moments, forces, linear acceleration, angular acceleration, and friction, with no simple "standard" rules to follow (e.g., the friction force does not vary in a fixed way with the direction an object is rolling). No matter how many times an instructor makes an effort to explain the analysis to the class, students still seem to struggle with the concepts. In an attempt to alleviate this issue and to create a motivating, active classroom environment, we have developed the Spool Inquiry-Based Learning Activity (IBLA). In an IBLA, a physical scenario is presented to students, who are asked to make individual predictions about what is likely to occur. After the students make their individual predictions, they discuss the scenario with their team (3-4 students). This group dialogue introduces the benefits of collaborative learning, in which students are able to help each other understand concepts. The team then performs the experiment, discusses the results, and attempts to explain what occurred and why. Once they reach a conclusion, the students are presented with a second scenario and repeat the process: predict-discuss-observe-explain. The instructor and teaching assistants move throughout the classroom during the cycle and gauge the classes' level of comprehension. Subsequent class discussions led by the instructor depend on how well the class understands the concepts. The process is repeated for a total of four scenarios. Applying this activity plan to the Spool IBLA, we ask questions such as, "If you pull lightly on the string wrapped around the inner diameter of a spool, in which direction do you think the spool will accelerate? In which direction does the friction force act?" The students perform the experiment by pulling on the string and noting the direction of the acceleration. The instructor then discusses the relationship between force and linear acceleration, and between moments and angular acceleration. Results of our initial assessment have found that the students thought the Spool IBLA helped them learn dynamics (4.2/5 on a Likert scale) and that they found the activity interesting and motivating (3.9/5 on a Likert scale). We will also present results from pre- and post-course scores on the Dynamics Concept Inventory and the individual and team predictions for each of the scenarios.

Introduction

While studying to become competent engineers, students are expected to learn course content, which consists of both conceptual and procedural knowledge, to collaborate, and to practice applying their knowledge using homework. Throughout their education, students hone their problem solving and teamwork skills, and ideally, build their conceptual understanding. The Cal Poly Dynamics Research Team is particularly interested in how strong conceptual understanding

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is achieved and in developing learning activities to support conceptual understanding. Using these activities during class time can effectively engage students in order to yield meaningful learning.

To date, our team has created several hands-on activities to engage students in conceptual learning. The activities allow the students to experiment with physical objects similar to those they might see in a homework problem, i.e., weights on a pulley, hollow and solid cylinders rolling down a ramp, gyroscopes spinning, and strings wrapped around spools pulled gently across a surface. The scenarios are designed to produce non-intuitive results, resulting in cognitive conflict. In this way, the activities intentionally challenge students to rethink their conceptual frameworks.

As part of this research, we identify the concepts used by the students as they piece together their observations in order to understand if meaningful learning is occurring. We also try to pinpoint how they have constructed their understanding and whether it is from observations in the world around them, learned in an introductory course prerequisite to dynamics, or something they have constructed by themselves using the information learned in the dynamics class in which they are currently enrolled. If a misconception is identified, we aim to tailor the activity to address and correct it. The overriding goal of this research is to provide students with a coherent framework that pushes them to better conceptual understanding.

Students enter dynamics classes with procedural knowledge gained in prerequisite courses focused on numerical calculations necessary to solve a dynamics problem. However, applying concepts as practicing engineering professionals takes more than being able to plug numbers into an equation and using a calculator to arrive at an answer. Certain dynamics topics are not intuitive or non-observable (i.e., friction between two surfaces or the mass moment of inertia), and do not lend themselves to being fully understood in a more profound way. Our research seeks to allow students to be able to "experience" the phenomena – such as energy or work – to make these concepts relatable by observing objects students can feel and see.

One measure of the effectiveness of these activities is through the use of the Dynamics Concept Inventory (DCI) [1], which is a pre- and post-course instrument developed to track how students' conceptual understanding of important topics changes throughout the class. The DCI contains multiple questions about eleven topics covered in the dynamics curriculum. The concepts covered by the DCI include those targeted by the hands-on activities we have developed, providing us with additional data to assess whether the activities are working as intended.

According to research by Laws et al. [2], students who are taught using the traditional lecture–example problem methods generally have a lower conceptual understanding of course material than those engaged in active learning. The data from Laws et al. given in Figure 1 show a dramatic increase in concept understanding for students engaged in inquiry-based active learning in a physics class.

Both traditional and active teaching methods can also be described as deductive or inductive. In inductive teaching, the direction of learning goes from a specific context to a general concept. The opposite is true for deductive teaching where the learning goes from theory to specific

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context. Traditional teaching methods take the deductive approach where the concept is introduced and moves toward specific example problems. We use the inductive method in our activities, where the students are given specific problems and are guided towards a more general understanding of the concepts.

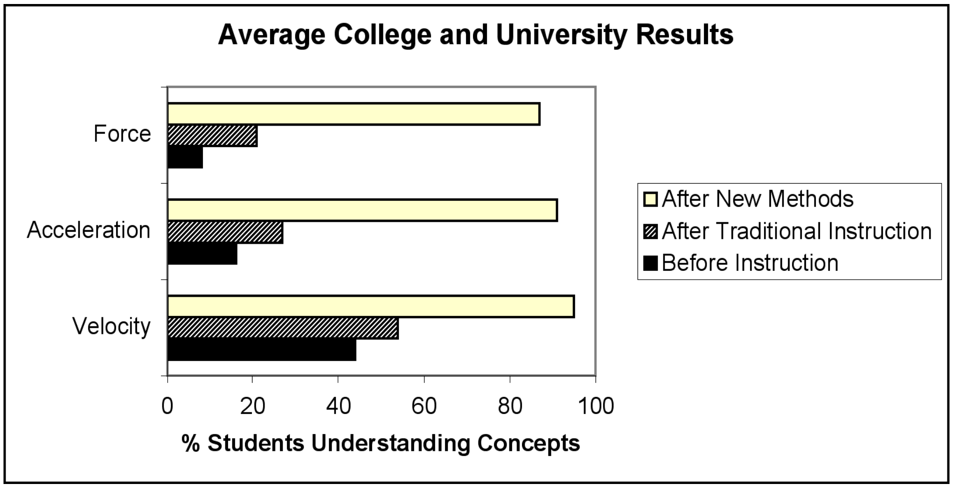

Figure 1. Data show that active learning methods results in dramatically increased conceptual understanding over students engaged in only traditional learning (from Laws et al.).

The Inquiry-Based Learning Activity (IBLA)

Although the exact definition of inquiry-based instruction varies somewhat between different investigators, we will use the defining features offered by Laws et al.[2] and highlighted by Prince and Vigeant[3] in Table 1. A defining aspect of an IBLA is that the physical world is the authority rather than the word of the professor or the calculations in the students' homework. Allowing the results of a physical experiment to communicate information to the student tends to be more effective than having a professor convey the facts. The IBLA procedure has students make a prediction about a physical situation then allows them to witness the result and draw conclusions from that result. The IBLA allows for more independence in learning, as it is not meant to be highly structured as in a laboratory experiment.

Figure 2 shows the IBLA learning cycle that begins with groups of 3-4 students being presented with a physical scenario and a number of choices for the result of that

(a) Use peer instruction and collaborative work
(b) Use activity-based guided-inquiry curricular materials
(c) Use a learning cycle beginning with predictions
(d) Emphasize conceptual understanding
(e) Let the physical world be the authority
(f) Evaluate student understanding
(g) Make appropriate use of technology
(h) Begin with the specific and move to the general

Table 1. Elements of Inquiry-Based Learning Activities

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scenario. Each student indicates their individual prediction on a worksheet, then the group engages in a discussion that may result in some of them changing their minds. The group then indicates the number of "votes" for each choice on a group worksheet they fill out together. The purpose of both worksheets is to assess the influence of "group-think" when it comes to individual student understanding. The group goes on to perform the experiment and discuss the results. The cycle begins again when a new scenario is presented to the group that is similar, but differs slightly in a way that either challenges the conclusions drawn in the previous scenario, or presents an opportunity to confirm the methods used to explain the previous results.

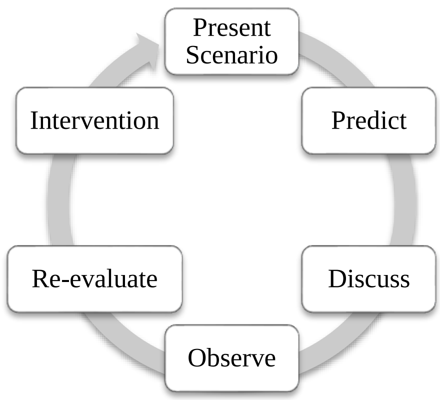

Figure 2. IBLA Cycle

Between subsequent activities, the professor may wish to "intervene" by giving a short explanation and presenting the students with information they can use in the next cycle of the activity.

The Spool IBLA

The Spool IBLA is designed to target the dynamics concepts of Newton's Second Law, friction, the relationship between net moment and angular acceleration, and the use of Free Body Diagrams (FBDs). In the IBLA, Newton's Second Law is explored through the interaction of the sum of forces being equal to mass times linear acceleration, and the sum of moments being equal to the moment of inertia times the angular acceleration. The use of FBDs along with Newton's laws of motion is crucial in making correct predictions because it allows students to visualize the interactions between forces, moments, and accelerations. Additionally, the IBLA is meant to address the common misconception that friction always acts opposite the direction of motion for a moving object. The students are also asked to differentiate between static friction and kinetic friction, especially as they relate to the concept of rolling with or without slip.

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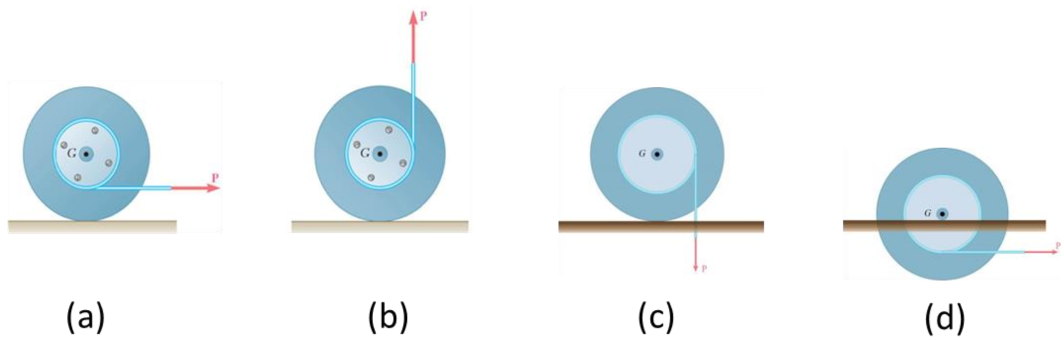

Figure 3. The four cases for the spool IBLA (only results using Cases (a) and (b) are presented here).

In each case of the Spool IBLA, the students are presented with a spool on a surface as shown in Figure 3. The students are tasked with predicting (a) which way the spool will travel when the string is gently pulled in the direction shown and (b) what direction the friction force between the spool and the surface is acting.

When given the first case, most students are observed to not know where to begin and simply use their intuition when making their prediction. After the first case, the instructor performs an intervention. He draws the FBD and Kinetic Diagram (KD), or Mass-Acceleration Diagram (MAD), and discusses the behavior of the rolling spool and how the FBD and KD can help predict that behavior. With this guidance, the students are allowed to continue. In the subsequent cases, we have observed the students using the FBD and KD to make their predictions.

We will discuss our intervention for Case B to provide an example of how we relate force, linear acceleration, moment, and angular acceleration. During the intervention, students are first asked to assume the friction acts to the right, and told to draw the appropriate free-body diagram. As part of a full class discussion, students then talk about the moment about the center of mass – they recognize that the net moment has to be counter-clockwise, which means that the angular acceleration would have to be counter-clockwise. If this is the case, for kinematic consistency, the linear acceleration has to be to the left. Since there is no force to cause this acceleration (assuming the friction is to the right), our assumption must be incorrect.

If we now assume friction is to the left, we see that this is possible; the moment due to the force P is greater than the moment caused by the friction, and the friction force "causes" the acceleration to the left. Similar arguments relating the direction of the friction force, moment, and the linear and angular accelerations can be made for the other cases. We can also discuss the fact that the weight must be greater than P to keep the spool touching the surface. Follow-on activities might discuss how this friction force is analogous to the traction force on the drive wheel of a vehicle, and how the moment caused by P is analogous to the torque caused by the engine.

Through this activity, the students discover that the direction of the friction force on a rolling body is not, in fact, related in any standardized way to the direction of rolling. This conclusion can be drawn from the first two cases where the spool travels in opposite directions, yet the friction force acts in the same direction for both cases.

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Assessment

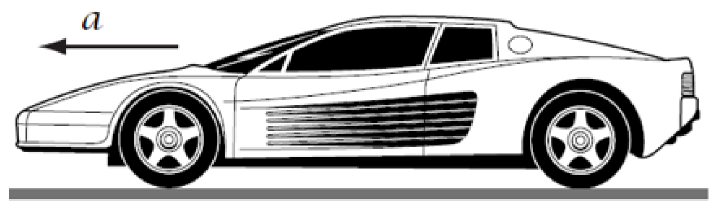

Figure 4. Automobile tire friction question on DCI: Find the friction force direction and expression for the front and rear tires.

The data we have analyzed up to this point spans the Fall 2012, Winter 2013 (2 different classes), and Spring 2013 quarters at Cal Poly San Luis Obispo. In each class, the students took the DCI quiz at the beginning of the quarter. For our research, we looked at the DCI question involving the friction force on the front and rear tires of a rear-wheel drive car (Fig. 4). This question requires the student to apply what they learned in the Spool IBLA and to show that they understand that the friction is not always in the direction of travel. Because it is not explicitly a spool being pulled along by a string, this is really a transfer question that can show whether or not a deeper conceptual understanding has been realized.

Near the middle of the quarter, the IBLA was performed in class. In addition, the students were tested on material involving rolling without slip on an exam. Towards the end of the quarter, the students took the DCI again to record their retention of the concepts. Finally, students submitted a survey to give feedback and compare the IBLA to other activities (homework, lecture, etc.) on whether or not the activity was helpful and interesting.

Results

The results in Table 2 show the percentage of correct answers on the pre- and post-activity DCI for the three dynamics classes evaluated. Only the post-activity scores for the *intermediate* dynamics class in Winter 2013 are available. The students in the intermediate dynamics class were expected to have already learned this material in dynamics, but the activity was performed in their class, and they took the DCI afterwards to provide additional data.

	Friction on Rear Tire		**Friction on Front Tire**	
Class	**Pre**	**Post**	**Pre**	**Post**
Fall 2012 Dynamics	29.0%	57.4%	29.0%	51.1%
Winter 2013 Dynamics	37%	42.9%	33.3%	35.7%
Winter 2013 Inter. Dynamics	N/A	55.9%	N/A	47.5%

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Spring 2013 Dynamics	44.4%	59.4%	29.6%	40.6%

Table 2. Percentage of correct answers for DCI questions

The results generally demonstrate a moderate increase in understanding rolling without slip concepts. The only exception is the Winter 2013 dynamics class where less than 10% gains were made. There is no "control" class in which the activity was not run. As a note, the spool concept is not directly tested on the DCI; the friction on the car tires is related to, but not the same as, the spool. Because of these facts, we cannot currently assign any causation from the IBLA in the improvement of DCI scores.

We also tabulated the data from the worksheets filled out during the activity used to mark the individual and group predictions for cases (a) and (b). The data shown in Table 3 through Table 5 show improvement in the individual student's ability to correctly predict the roll direction throughout the activity. It also shows an increase in correct predictions after the students were given a chance to talk with others. There doesn't appear to be a trend in correct predictions of friction directions. We believe that this is because the friction force is not directly observable and is a particularly difficult concept. As a result of this, we have recently altered the intervention that we provide, and added cases (c) and (d) to provide additional practice for the students. We are also working on an interactive simulation to give the students additional practice on rolling scenarios – this will target the friction direction, since this is not easily visualized in the physical hands-on activity.

	Individual Predictions	Team Predictions
Horizontal pull – motion direction	26%	35.7%
Horizontal pull – friction direction	56%	75%
Vertical pull – motion direction	91%	92.9%
Vertical pull – friction direction	32%	42.9%

Table 3. Percent Correct Predictions: Winter '13.

Pre-activity Quiz		Team Predictions	
Horizontal pull – motion direction	52%	Horizontal pull – motion direction	73%
Horizontal pull – friction direction	66%		
Vertical pull – motion direction	86%	Vertical pull – motion direction	84%
Vertical pull –	45%		

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friction direction			
	n = 65		n = 63

Table 4. Percent Correct Predictions: Intermediate dynamics, Winter ’13

	Individual Predictions n = ~15	Team Predictions n = 30
Horizontal pull – Motion direction	9%	20%
Horizontal pull – Friction direction	44%	46.7%
Vertical pull – Motion direction	59%	76.7%
Vertical pull – Friction direction	72%	60%

Table 5. Percent Correct predictions: Spring '13

The post-activity survey used a Likert scale to assess the students’ response to the Spool IBLA. The results in the Table 3 show that the students found the Spool activity helpful and motivating in learning the dynamics concepts. However, the activity was ranked lower on the list of importance relative to some other class activities. In fact, the students reported that lecture was the most important activity to their learning.

Pulling the spools helped me learn dynamics. (Likert scale)	Pulling the spools was interesting and motivating. (Likert scale)	Importance of Activity relative to other activities. (1 is most, 11 is least)	Class session
4.18/5	3.81/5	7.12/11	Fall ‘12
4.27/5	3.92/5	6.31/11	Winter ‘13
3.6/5	3.3/5	6.7/11	Spring ‘13

Table 5. Survey Results

Further Research and Improvement

Several improvements are currently being tested to improve the effectiveness of the Spool IBLA and to gather more data. A newer version of the activity includes the fourth case, whereas the data presented here are from an activity that only included scenarios (a) and (b) in Figure 1 as well as a case where the string was pulled at an angle. We now include all four scenarios with two interventions after case (a) and case (b) and one at the end of the activity. We are still using prediction sheets to track how the students’ understanding progresses through the activity. Initial data is showing promising increases in correct predictions through the IBLA.

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In addition to continuing the activities in classes with students working in groups, individual students have been video-taped doing the activity using a "think-aloud" protocol[4]. The "think-aloud" involves a one-on-one interview where the student participates in the IBLA in front of a member of our research team. While engaged in the activity, the student is asked to talk through everything they are thinking. The whole process is recorded for analysis at a later date. The purpose of this research is to take the student out of the group setting where they may be influenced by "group-think" in order to pinpoint difficulties the student experiences or misconceptions the student has. This is an effort to make specific changes to the Spool IBLA (i.e., when the professor intervenes and the verbiage used in it) that address these problems and increase its ability to help students grasp the concepts.

One aspect of the Spool IBLA that we think poses the biggest hurdle for students' conceptual understanding is that the friction force is not observable. The potential solution to this would be to visually show the friction force using a computer simulation. There is a question as to whether the simulation would be better than the activity or not due to less credibility or believability of the software. Feedback from students about such a simulation would decide if it would be a beneficial addition to the activity.

Conclusion

The data we have presented in this paper shows little correlation between the Spool Inquiry-Based Learning Activity and a marked increase in scores on the Dynamics Concept Inventory. However, the prediction sheets show more promising results. Overall, the students' ability to correctly predict the direction the spool will roll increases from the first to the second case. The main difficulty students face is predicting the friction force direction, as it is not directly observable. The post-activity survey shows a generally positive attitude towards the use and motivation the IBLA provides for learning concepts related to an object rolling without slip. The Cal Poly Dynamics Research Team is currently conducting more research in order to improve the Spool IBLA.

Acknowledgments

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Distance Learning Requirements for Vetting Curricula

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Abstract

Educational objects (eObjects) such as YouTube laboratories and pod lectures deluge the internet. Additionally, MOOCs and distance learning introduce escalating challenges for higher education and institutional educators, particularly, in the area of course content validation. How can these eObjects be validated and trusted? Vetting of course content in the traditional university is accomplished by the oversight established by faculty, institution and accrediting body review and assessment. The internet presents a new vehicle by which anyone can offer course content for consumption by distance learners in a non-structured and non-vetted modality. This paper presents a viable solution to the try-not-try MOOC conundrum, called the Virtual Instruction Cloud (VIC). Much of the uncertainty for embracing the MOOC model is financial in nature, but, additionally, the potential for losing control of valuable course IP assets by offering the courses for free is a significant determining constraint. VIC can do so in an accommodating manner to preserve the traditional higher educational institution model of monetization, and control vetting and provenance of curricula content; while still inviting the contribution of new curricula developed outside of the traditional academic system. Vetting of course material, to give it authenticity, can still be orchestrated and performed by the traditionally accredited institutions. Furthermore, the provenance of the material and proof of course IP ownership can be properly tracked by a relational database. Encapsulation makes it possible to preserve the integrity of the asset, provides the ability to restore it to its pristine state in the event of malicious tampering, and makes it possible to maintain non-repudiation of its recorded provenance. It, also, provides a process to track enhancements made to a course module. The outcome of this paper is to demonstrate a VIC solution to leverage the challenges presented by the openness and transparency of the internet. The authors posit that this approach to vetting of curricula content, whether it originates in traditional academia, or from the openness of the internet will promote open contribution of new material and ensure the proper remuneration to the IP owner of any traditional or eObject employed by MOOCs or other distance learning services.

Keywords: Accreditation, cloud, curricula, digital signature, encapsulation, peer review, provenance, vetting, Virtual Instruction Cloud

Introduction

The openness, usage, growth, social nature, leading technology, and mobile deployment of the internet present challenges to vetting of educational content that extend far beyond peer reviews of academic journal papers. Vetting, in this context, implies the process of examination, review,

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validation and authentication of instructional content relative to a standard of excellence and fact. Five identified aspects of the vetting process are: 1) the creator of the content; 2) the content; 3) the qualifications of the assessor: “vettor”, reviewer or referee; 4) the basis of the standard; and 5) bias introduced by the process. A vettor is someone who checks or investigates an item or individual to ensure compliance with a pre-defined standard. Increasingly, vetting is now required of instructional objects of every variety: essays, manuscripts, articles, textbooks, precision pod lectures. video lessons, videos, Power Points, music, demonstrations, tutorials, lab exercises, microcontent[1] blocks of blogs, Wikis, and podcasts, and entire courses.

The outcome of this research identifies an approach to vet curricula content objects to meet a range of defined standards for the explosive number of distance learners empowered by the openness of the internet.

Internet Openness Accelerates Data Consumption

Data consumption on the internet dynamically grows at a 21% compound annual growth rate[2]. In 2011, Cisco estimated total monthly global internet traffic to be 20 petabytes, the equivalent of all the printed and digital contents of the U.S. Library of Congress[3,4]. Total annual internet IP traffic is forecast to exceed 1 zettabyte (one million petabytes) in 2016. This will be over a four-fold increase in five years. Internet video streaming and downloads account for ever-increasing bandwidth loads and are forecast to comprise 76% of all consumer internet traffic in 2018. Over 55% of all IP traffic will cross over content delivery networks. Both video usage and content delivery will place heavy loads on educational learning management systems and distance learning processes[2].

Ease of Access Facilitates the Internet as a Primary Information Resource

Individuals seeking immediate answers on virtually every topic currently turn to the internet as the primary information resource because it is so easy – especially when using mobile computing devices that are on their persona. Studies regarding inquiries for news, government, healthcare and commerce indicate that 65% of the populace and 80% of internet users expect the Web to have the answers and will turn to it as their first resource on these topics[5].

- *Educational Objects Deluge the Internet*

The Internet is transformative, “a catalyst for innovation, communication, economic growth and social development”[6]. McKinsey reported in 2011 that the internet accounts for 3.4% of the global GDP, and if it were a commercial sector it exceeds agriculture, utilities and education and falls just below the transportation sector[7]. The latest Cisco Visual Network Index forecast for 2013-2018 estimates that fifty-five percent of internet traffic will be content delivery and over half will originate from non-PC mobile devices[2]. With video broadband tripling by 2018 video on demand (VoD) delivery will double; channeling much of educational content delivery to mobile devices. The use of video courseware will escalate making pod lectures and video lectures preferred delivery modalities.

- *Distance Learners Pursue Ease of Access*

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Learners, in a similar fashion to other web users, turn first to the internet and usually begin with YouTube in learning how to do something of a technical nature even before consulting a user's manual. If the instruction works, then great! If not, then simply try the next link listed. Consequently, courseware quality and vetting become critical current and future issues for education and distance learning.

Internet "Openness" Enables and Encourages End-User Contributions

The Internet Society, the non-profit organization that manages the internet, issued a white paper in 2013 on "The Value of Openness for a Sustainable Internet – A Proposed Vision for the Post-2015 Agenda."[6] Economic and social development, as represented in Fig. 1, are cultivated with an ability to innovate without constraint using open source, free computer tools. Openness fosters innovation that relies on "users' ability to freely and openly create, and share information and ideas."

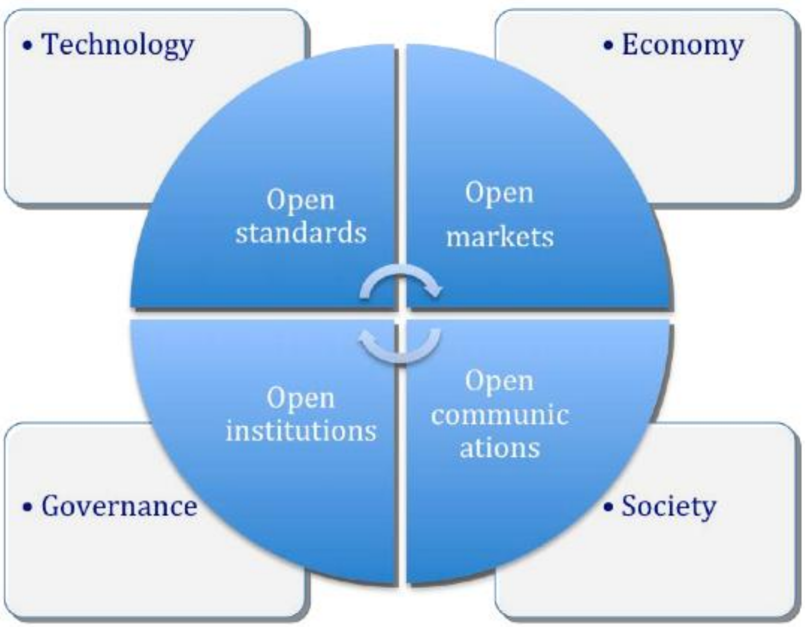

Figure 1. Internet Openness[6]

Recently, new software tools have provided many fledgling instructors with the ability to produce an acceptable quality video lecture or training video. This sudden access to open source and/or low cost technology has resulted in a massive increase in video based instructional content.

- *Does the Internet Openness Promote a Variety of Educational Vetting Standards?*

Much of the innovative educational content, however, involves creators without degrees and traditional affiliation with accredited institutions of higher learning. Vetting the variety and volume of such creative product becomes an overwhelming challenge.

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The authors posit that internet vetting is additionally complicated by the existence of a multitude of educational standards, at all levels of education, in over 150 nations. Consider just a sampling of U.S. standards established for a) accredited universities (of at least two varieties in the U.S. – regional and national accreditation), b) state accredited colleges and vocational training, c) professional and vocational certifications, and d) academic publications. To facilitate the discussion of this paper "vettors" will be assumed to be vetters linked to a specifically defined educational standard. Hence, we have a variety of standards, each with its set of discipline-qualified vettor-reviewers.

Background

Distance Learning

Student learning by means of the cloud has become a collaborative, or social process. Students do not see social interaction as "jumping on the Internet" but, rather, as a lifestyle.[3] The Educause publication, *The Tower and the Cloud*[16], emphasized that the emergence of "cloud" technology has significant implications on us, individually and collectively, for higher education as we know it. Katz posits that Information Technology (IT) "… will cut its own channels, leading to the creation of institutions that differ from those of today".

- *Massively Open Online Courses (MOOCs)*

MOOCs and distance learning introduce escalating challenges for higher education and institutional educators, particularly, in the area of course content validation. Vetting of course content in the traditional university is accomplished by the oversight established by faculty, institution and accrediting body review and assessment. The internet presents a new vehicle by which anyone can offer course content for consumption by distance learners in a non-structured and non-vetted modality leaving the consumer student in a quandary, not knowing the academic truthfulness of a given offering.

How Trustworthy is Internet Information Material for Educational Purposes?

A significant portion of internet usage is informational in nature but how trustworthy is it in an educational context? The fact that anyone, credentialed or not, can publish content along side the most credible and validated material precipitates discussion that questions the validity of such information. As educators, we welcome this "openness" that leads to unbounded creativity. The social media revolution, that we are experiencing, builds on total openness and presents new learning opportunities and modalities. As educators, we question how to best assist learners in their almost insatiable hunger for knowledge. Internet content, however, spans the entire spectrum of credibility from proven scientific fact – to theories – to fraud. To date there is no credibility index or metric associated with internet educational content, and, based on academic freedom objectives, none appears imminent.

- *Participatory, Consensus-driven Peer Review on the Internet*

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An important internet premise has been to allow "…people to connect and craft together technical and social change through a participatory and consensus-driven process."[6] This is reflected in the peer review public comment process of the Internet Engineering Task Force (IETF) Request for Comments (RFC) process shown in Fig. 2. This is an example of participatory, consensus-driven peer review as implemented by the IETF.

Organization	Type of Review	Author Contribution	Editors	Designated Reviewers, Referees (Peers)	Public Reviewers (Peers)	Provenance	Quality Assurance
Internet Engineering Task Force (IETF) (ISOC)[4]	Request for Comments (RFC)	Public, IETF Work Groups	RFC Editor	IETF and Internet Engineering Steering Group (IESG)	Public comment reviewed by ISOC	IETF Trust copyright	ISOC and IETF

Figure 2. IETF: Participatory, Consensus-driven Peer Review

- *Biased Vetting of Branded Content on the Internet*

Individual educational web sites that have developed a known brand, such as Khan Academy, provide their own vetting through content specialists, a board of reviewers and partnerships with institutions like NASA, The Museum of Modern Art, The California Academy of Sciences, and MIT[8]. Wikipedia, perhaps the most well known educational content provider brand on the internet, originally based its product on the "wisdom of crowds" concept[9]. Wikipedia provides vetting through its management, Wiki editors, editor/writer Wikipedians in the tens of thousands

Organization	Type of Review	Author Contribution	Editors	Designated Reviewers, Referees (Peers)	Public Reviewers (Peers)	Provenance	Quality Assurance
Wikipedia	Wikimedia control/bias	Articles Primarily by Wikipedians	Wiki Editors Wikipedians	Wikipedians	Public but edited by Wikipedians	Article and Comments Archived	Wikipedians and Wikimedia control/bias
Kahn Academy	Kahn Academy control/bias	Content Specialists	Content Specialists	Board of Reviewers	None Specified	None Specified	Board of Reviewers control/bias

Figure 3. Biased Vetting: Wikipedia and Kahn Academy

in number, and public peer reviewers under the direction of the Wikipedians. Wikipedians are predominantly anonymous. Both Kahn Academy and Wikipedia exercise very tight control over the creation of content and the amount of freedom for external public contribution – hence, the authors' terminology "biased vetting", biased according to the dictates and philosophy of management.

- *Academic Journal Peer Review*

The first editorial peer-review publication may have been the Royal Society of Edinburgh in 1731. It was not until 1967, however, that the journal *Nature* instituted formal peer review for its academic publications in a process that we would currently recognize[10]. *Nature's* present process is shown in Fig. 4. where anonymous referees are used with no public peer review involvement. Furthermore, it continuously evaluates other options for improvement as

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Organization	Type of Review	Author Contribution	Editors	Designated Reviewers, Referees (Peers)	Public Reviewers (Peers)	Provenance	Quality Assurance
European Geosciences Union Journals e.g. *Atmospheric Chemistry and Physics*	Two-Phase Peer Review and Publication: 1:Open Public Discussion paper posted on Internet (BGD) and 2: Final Response on website (BG)	Public scientific paper (Phases 1, 2)	Journal Editor (Phases 1, 2)	Signed or Anonymous Comments (Phases 1, 2)	Scientists Register and Sign comments (Phase 1)	Paper and Comments Archived	Public Peer Review Interactive Public Discussion enhance quality
Nature	Peer Review and Publication: Review by all editorial staff Review by external referees Provision of relevant prior art to referees Double-blind peer review is an option	Public scientific paper	Journal Editors	Anonymous Referees	Not used	*Nature* copyright	Qualified referees actively recruited

Figure 4. Academic Journal Peer Review

Ackerman[9] and others have reviewed in attempts to more interactively involve the public in the review process. Moore stated, "In other words, we understand the peer-review system, and use it as a filter to sort the wheat from the chaff. … the peer-review system has its flaws. My own view is that it's the least-bad system that can be devised, and that, although it might need tinkering with, its fundamentals should remain intact."[11]

As summarized in Fig. 4, the European Geosciences Union Journals (EUGJ) instituted a two-phase peer review and publication process with a) an open public discussion paper posted on the internet (BioGeosciences Discussion - BGD), and b) a final response posting on a website (BioGeosciences - BG).[12] In contrast to the *Nature* journal process, the EUGJ reviewers must sign their comments and authors respond. Likewise, in the public discussion phase scientists must register and sign their comments prior to the second phase of final publication. For academia, this approaches the openness and transparency that the internet represents with a true participatory, consensus-driven peer review. EUGJ maintains that this fosters scientific discussion; deters submission of substandard manuscripts (as it only has a 20% rejection rate); conserves reviewing capacities; and integrates flexibly into existing journals, publishing systems, repositories and interactive discussion forums. Quality assurance appears to result from this approach as EGUJ was ranked 12th out of 169 journals.

One must exercise caution, however, and avoid attempting to make academic peer review into a popularized, publicly open voting process. Many academic concepts involve the scientific process and are not amenable to a public, consensus-driven vote. Lagoze observed, "There is a line between the wisdom of crowds and the wisdom of the few that is challenging to draw."[9]

- *Credibility Assessment of Internet-based Information*

How to assess the credibility of internet-based information objects is an increasingly difficulty subject and has been continuously discussed for over twenty years. Among the set of *Nature* articles in 2006 that openly addressed peer review in the journal editorial process was one titled

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"I Don't Know What to Believe", an opinion voiced by many internet users regarding the deluge of internet information.[13]

- *Challenges to Traditional Academic Peer Review*

In spite of all the academic journals are doing, the sheer volume and pace of information enabled by the internet and publishing tools such as weblogs demands novel solutions.[9] Furthermore, the innovative distance learning modalities, such as Massive Open Online Courses (MOOCs), extend the requirement of normal curricula accreditation from a brick and mortar university to the online modality. The accreditation of brand name universities is extended in name only with the MOOC courses, and therefore credit toward a degree and traditional articulation issues still remain ill-defined. Among the specific challenges that the internet raises to the traditional academic peer review process are the following:

- Volume of instructional material
- Internet pace
- Diversity of curricula eObjects
- Contribution of material by non-certified writers, creators and developers
- Recruiting qualified, certified vettors
- Eliminating anonymous reviews and comments
- Authenticating authors, vettors, public reviewers and learners
- Tracking comments by reviewers
- Tracking provenance of curricula eObjects
- Digitally, securely protecting the integrity of eObjects

The methods necessary to determine how universities that contribute courseware to MOOCs and other distance learning modalities will resolve the associated articulation issues is not within the scope of this paper and deserves future consideration. The manner in which accredited universities' courseware, vetted in their respective domains by their faculties, is certified for use in distance learning situations, is likewise, still under discussion in the marketplace.[3]

Experiments to Modify Academic Peer Review

The set of *Nature* references in this paper review a focused attempt in 2006 to consider alternate processes for peer reviewing manuscripts for the *Nature* journals.[14] No major change was found to be recommended even after conducting various experiments with alternate processes. EUGJ, on the other hand, opted to make several changes even removing referee anonymity and establish its current two-phase process, shown in Fig. 4, that it felt was more in step with the challenges presented by the internet. Another attempt was the Postgenomic.com blog, a scientific blog aggregator experiment, to link a paper to a blog post and find its DOI or PubMed ID, and collect metadata and comments in an organized fashion.[10] A DOI is a character string digital object identifier that uniquely identifies a digital object such as a pdf document that is maintained for the life of the object. The metadata may contain URL information that helps locate the object. A publisher need only update the metadata URL when the URL changes to continue being able to

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find an object. One *Nature* citation used in this paper references “doi:10.1038/nature04997” and is one of approximately 85 million DOI registered digital objects.[15] Placing this “doi” reference into a browser brings up links to the archived digital object in html format.

Curricula Accreditation is a Vetting Process

Vetting of course content in the traditional university is accomplished by the oversight established by faculty, institution and accrediting body review and assessment. In the case of National University the Western Association of Schools and Colleges (WASC) is the regional accrediting institution. The accreditation process under WASC supervision involves faculty members, graduate and undergraduate council committee members who fulfill the vettor function on curricula content. Articulation, the process wherein university A accepts an accredited course from university B as an equivalency for degree granting is based on this mutual assignation, by both A and B, of faculty members as vettors.

Future Peer Review Using Internet Technology

Internet curricula offerings, through MOOCs or other means, rely upon the accreditation and vetting by the university that offers the online course in order to establish the validity of the offered curriculum. Articulation, the process whereby credit is given for completing a MOOC course is undergoing discussion and definition.

Regarding publications, Akerman further states,

> “For the certification role, the current system of peer review has enduring value, ensuring that an article passes certain standards of scientific quality and integrity. It requires considerable knowledge and expertise, as well as a wide base of contacts within academia to be able to select appropriate reviewers. But the article itself could live an independent life on web pages or in institutional repositories without ever being published in a journal. Since a blog is fundamentally a publishing technology, might a scientist's blog be the authoritative source for his or her academic output? An article or blog entry submitted to, and passed by, a stand-alone peer review service might be recorded in a public registry, or be digitally signed as part of the certification process.”[9]

The authors posit that vetting of internet eObjects and non-university-owned course content could be accomplished by a process that mirrors the publication peer review process.

Research on Vetting Internet Educational Content

Virtual Instruction Cloud Implementation: Vetting, Provenance, and Encapsulation

Vetting of course material, to give it authenticity, can still be performed by the traditionally accredited institutional processes and orchestrate vetting in the open-source model of the internet. The integrity of the content material can be secured by cryptographic encapsulation

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where digitally signing is one means of achieving this. Furthermore, the provenance of the material and proof of course IP ownership can be properly tracked, and, in turn, encapsulated and archived in a relational database. Encapsulation makes it possible to preserve the integrity of the asset, provides the ability to restore it to its pristine state in the event of malicious tampering, and makes it possible to maintain non-repudiation of its recorded provenance. It, also, provides a process to track enhancements made to a specific course eObject module.

The Virtual Instruction Cloud (VIC)[3,17] is the outcome of research by the authors and provides for 1) the authentication of all users: authors, creators, vettors, instructors and students; 2) the vetting of all eObjects; 3) the tracking of eObject, origin and modification, provenance; and 4) the encapsulation (a digital signature is one form of encapsulation) of all eObjects and proof of provenance and deliverable completion in the case of reviews, comments, assignments, labs, exams and courses.

Fig. 4 summarizes the vetting, provenance and encapsulation processes that are part of VIC.

Organization	**Type of Review**	**Author Contribution**	**Editors**	**Designated Reviewers, Referees (Peers)**	**Public Reviewers (Peers)**	**Provenance**	**Quality Assurance**
Virtual Instruction Cloud (VIC)	Multi-Phase, Evolving Peer Review, Vetting and Publication: 1: Open Public posting of object or link to object 2: Proof of Provenance 3: Peer vetting 4: Encapsulation (aka Digital Signature)	Contributed/ Licensed Objects: Articles, papers, PPTs, Videos, YouTubes, courses, MOOCs, pod lectures, virtual labs, graphics, animations	VIC Editors	VIC Registered Vettors	VIC Registered Peers	All objects and vetting comments tracked and encapsulated proving origin with time-date stamp; Changes tracked from origination; Contributor IP ownership is honored	**VIC is a Trusted Third Party for Contributors:** Contributor protection for origination of IP and object content; Object integrity, intellectual property (IP) designation, licensing, and non-repudiation assured by encapsulation technology

Figure 4. Virtual Instruction Cloud Vetting of All Digital eObjects

- *Tracking Provenance of Curricula Objects*

The issue of eObject intellectual property origin and ownership is addressed by the VIC Structure Provenance and Encapsulation module (212) shown in Figure 5.

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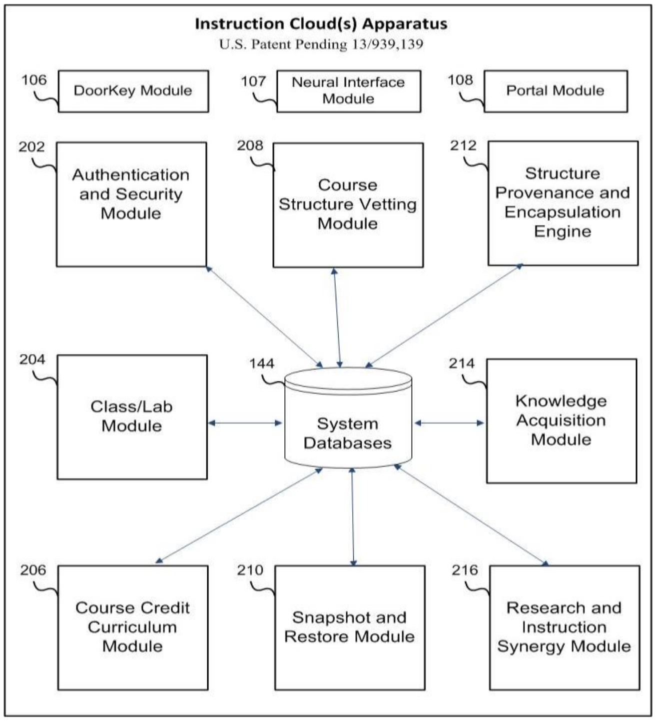

Figure 5. Virtual Instruction Cloud Modules

This module ensures the integrity of all content objects in the Virtual Instruction Cloud. The module encapsulates all content objects with a digital algorithm that ensures 100% content integrity and attribution. In addition, this module records the author and the date/time stamp of encapsulation. One unique aspect of the date/time stamp metadata is the use of time server appliances to synchronize the encapsulation algorithms results with the atomic clocks maintained by the National Institute of Standards and Technology. This method ensures the auditability and traceability of all content objects maintained in the VIC. Encapsulation addresses the issue of content origin and structural integrity. The provenance feature of the encapsulation engine addresses the issue of ownership. The VIC has many features which facilitate the multiple steps required to fully vet specific content objects. The provenance function of the encapsulation engine records the complete history of this vetting process and provides the traceability necessary for attestation of intellectual property ownership. The combined functions of Structure Provenance and Encapsulation Engine provide a rigorous method which will allow academic institutions to rely on accredited, open-source learning materials sourced from the World Wide Web.

Conclusions

Meeting the Challenges by Leveraging Internet Characteristics

Research that led to the beginning implementation of Virtual Instruction Cloud modules (refer to Fig. 5) suggests that the challenges previously specified may be resolved by leveraging the very

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internet characteristics that have appeared to be overwhelming. This can be achieved by building on the foundation already established by traditional academia and of accreditation, certification and peer review vetting of, not just publications, but the vast quantity of open source contribution of eObjects now appearing on the internet. Furthermore, all of this builds on the sub-layer of the philosophy of the internet to freely and openly create, and share information and ideas by the crowd through the cloud.

- *Volume of instructional material*

VIC is scalable and designed to expand with the volume of eObjects: essays, manuscripts, articles, textbooks, precision pod lectures, video lessons, videos, Power Points, music, demonstrations. tutorials. lab exercises, microcontent[1] blocks of blogs, Wikis, and podcasts, and entire courses.

- *Internet pace*

Embracing the creativity of the contributor space beyond traditional academia will meet the accelerating pace of internet-time and allow learners to "pull" content, each, at her own pace.

- *Diversity of curricula eObjects*

In the "open world" traditional academia has focused on vetting publications. Now, using VIC's Structure, Provenance and Encapsulation Engine, academia and content experts can vet all eObjects ensuring quality control over content for all learners K through university and professional certifications.

- *Contribution of material by non-certified writers, creators and developers*

eObjects are creatively developed by non-certified writers but can be validated by experts both in industry and academia following the peer review models of publications like Nature and Biogeosciences. Searching the internet for new content and collaborating with researchers in all fields will energize the contribution of the social media focused crowd.

- *Recruiting qualified, certified vettors*

Tapping the existing, already certified academic vettors from accredited academic institutions is crucial to the proposed vettor model. Additionally, bringing into the vetting community experts in industry and the professions is fundamental to the model. Wikipedia, Kahn Academy, Nature, Biogeosciences and other publishers have established exemplary networks and processes that utilize reviewers and vettors.

- *Eliminating anonymous reviews and comments*

The authors posit that the experimentation and experience of Biogeosciences Journals in requiring all reviewers to be registered and openly provide signed comments and reviews, following the model of the Internet Society will precipitate an open and transparent vetting process for eObjects.

- *Authenticating authors, vettors and public reviewers*

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The utilization of Public Key Infrastructure technology to require all authors, vettors and public reviewers to be authenticated by digital certificates is fundamental to the VIC model of vetting, tracking provenance and encapsulation of all usage of eObjects.

- *Tracking comments*

The ability of linking authenticated reviewer and public comments and archiving the same is a basis of tracking comment provenance. Such action preserves the openness of the internet and its systems.

- *Tracking provenance of curricula eObjects*

Proving the source of academic creativity and contribution has best been accomplished for 120 years through journal peer review. The receipt time-date stamp of a paper has been a primary proof of provenance of creativity. Even then, there are reported incidents of reviewers "snatching" ideas from submitted manuscripts especially in an anonymous review scenario. Hence, this is one of the reasons Biogeosciences Journals has elected to eliminate anonymous reviews. In the case of eObjects being developed and made available for free on the internet, proof of provenance and any associated IP licensing will provide protection to the creator and motivate greater contribution. In the case of traditional academic institutions, eObject ownership by a university can be proved by tracking provenance. Additionally, modifications made to eObjects can be tracked, likewise, by the provenance process.

- *Digitally, securely protecting the integrity of eObjects*

All creation, review, vetting and provenance tracking processes can be time-date-stamped and encapsulated (e.g. digitally signed) by all individuals or processes that create, modify or use an eObject. Such encapsulation will preserve the integrity of the eObject and establish the non-repudiation of the intellectual property. Hence, the developer who has an interest in being recognized for her creativity and potentially receiving remuneration in its usage can preserve the usage basis of her intellectual property by encapsulating her eObject. Subsequent changes to the eObject, or its inclusion in curricula, can be established by provenance and encapsulation validation.

The authors posit that these perceived challenges can be leveraged to produce a vibrant academic infrastructure for distance learners where eObjects are properly vetted and whose provenance can be established.

Recommendations for Future Research

Immediate plans are under development to facilitate an experimental environment for 1) authenticating eObject creators, vettors and learners/users; and 2) establishing the provenance tracking and encapsulation processes for eObjects.

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Computer Lab Provisioning:
A Review of Current Educational Practices

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Abstract

Traditionally, brick and mortar universities and junior colleges have delivered computer laboratory exercises via dedicated equipment resources in the classroom. Current trends in higher education have seen the classroom setting evolve into a distance learning environment. Students enrolled in distance learning programs access the educational classroom using internet based learning management systems (LMS). LMS products such as e-College and Blackboard Learn provide a rich toolset for instructor's use in the virtual classrooms which have become a common part of the distance learning experience. This paper analyzes a survey of Computer Science faculties from multiple academic institutions who were asked to provide details on the laboratory environment used in Computer Science courses. Analysis of the respondent's answers provides insight into the relationship between departmental responsibility for course content and the management services rendered by the institutions' Information Technology departments. The survey, also, includes information on how the laboratory exercises are tied to specific text books, the frequency the labs are updated, and the impact of the budget cycle upon the introduction of new resources. This paper presents the survey results along with relevant statistical information. The findings indicate that there exists a mixed correlation between text book learning outcomes and laboratory exercises. The results suggest that the provisioning of computer labs to deliver hands-on instruction in computer science courses varies greatly between institutions, and, particularly so, in distance learning programs. It is unfortunate that labs are frequently an afterthought appendage to an existing textbook. Although there are a few exceptions, the authors posit that computer lab provisioning processes are in their infancy, and should be more logically designed and strategically deployed in an integrated fashion with learning outcomes and textbook content.

Keywords: Distance learning, learning management systems, laboratory equipment, text books, workbooks, virtual laboratory, experiential learning, computer science, information technology

Introduction

The survey results presented in this paper focus on the delivery of experiential, hands-on learning resources by provisioning computer science labs. The survey data was obtained from a joint survey project conducted by Pearson Education and iNetwork, Inc. The schools included in the study had either undergraduate and/or graduate level cyber security degree programs. The faculties who responded to the survey were active instructors with direct knowledge of their school's computer laboratory resources. The project objective was to gather information on a

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large variety of topics which affect the provisioning of computer science labs used in higher education degree programs.

This paper categorizes the survey responses into the following topical groups:

Group Number	Description
1	General Information
2	Budgetary Information
3	Curriculum Learning Objectives
4	Lab Management Responsibility
5	Lab Technical Features
6	Hardware
7	Learning Management System Interface

Analysis of the respondent's answers provides insight into the relationship between departmental responsibility for course content and the management services rendered by the institutions' Information Technology (IT) departments. The survey, also, includes information on how the laboratory exercises are tied to specific text books, how often the labs are updated and how the budgetary cycle impacts the introduction of new resources.

This paper presents the survey results in the next two sections. The results are interpreted in two formats: 1) a textual list of Figures and Questions are presented first, along with commentary from the authors on questions found to be of particular interest; and 2) a graphical representation of the responses which includes statistical information typically presented as a percentage.

Textual List of Survey Questions

The rationale for the initial presentation of the questions in a textual list format is to familiarize the reader with the broad scope of the survey, and to better prepare her to assimilate and interpret the large amount of data that appears in the Graphical Survey Responses section. Some, but not all of the Figures/Questions presented in this section will contain commentary from the authors. Specifically, this section provides a venue for the authors to present their interpretation of results which are of particular importance in their analysis of current educational practices in computer lab provisioning.

The findings indicate that a mixed correlation between text book and laboratory exercises exists. The results suggest that the provisioning of computer labs to deliver hands-on instruction in computer science courses varies greatly between institutions, and, particularly so, in distance learning programs.

Group 1 - General Information

Figure 1/Q7: Annual Enrollment (in the entire computer science program)

Figure 2/Q28: Can your students access the lab remotely?

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Commentary: The question "Does your school have a lab?" was not asked directly. For the sake of clarity, this question will be added to future surveys. However, interpretation of the raw results reveals that only one school did not have a lab. Of those schools with labs, more than one-quarter of the respondents did not provide students with remote access.

Group 2 - Budgetary Information

Figure 3/Q13: What is the Annual departmental cost (budget) for lab equipment, maintenance agreements and software license updates?

Commentary: Most of the respondents did not know laboratory cost specifics. This indicates that decisions on provisioning (equipment costs, software licenses and maintenance agreements) are typically made by program administrators rather than faculty. Two schools indicated they had an annual lab equipment budget of an irrationally low amount of $5,000, substantiating, again, the finding that faculty are usually not involved in the budgetary or acquisition process.

A seminal computer security conference was held at West Point Academy in 2002 at which Padman and Memon held an IEEE Information Assurance Workshop and stressed the "requirement of a laboratory facility that will reinforce concepts taught in class with hands-on experiences."[1] In direct contrast, however, barely four years later, Hay and Nance from the University of Alaska presented a paper at the Colloquium for Information Systems Security Education (CISSE) which described their ability to repurpose surplus equipment and deliver a functional lab "for a cost of less than $200."[2] The dichotomy between these two positions ("experiential learning is vitally important" versus "we have no funds to create a lab") is a recurring theme that the authors identified by research into this topic thirteen years later. This lack of acceptance and implementation may have an origin in the financial decision-making process that still remains with an inadequately-informed, cost-conscious administration which does not yet recognize the vital need for hands-on learning in the study of computer science.

Figure 4/Q14: How are lab costs tracked? (by course, by class, by student, other)

Figure 5/Q15: Do you charge a lab fee?

Commentary: Half of the respondents answered "Yes" to this question. It would be interesting to know how much and also if the fees collected went toward the operation and/or improvement of the laboratory environment.

Figure 6/Q47: If you could implement new labs as an operating expense, would that enhance your instructional flexibility?

Commentary: Again, half of the respondents answered in the affirmative. This positive response indicates that even though most respondents did not acknowledge having knowledge of budgetary values and/or process, faculty does have an expectation that moving from a capital equipment acquisition process to an outsourcing model would enhance instructional flexibility.

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Group 3 - Curriculum Learning Objectives

Figure 7/Q17: Who creates the lab assignments?

Figure 8/Q18: Do you have a separate lab workbook that contains course specific lab assignments?

Figure 9/Q19: If Yes (to Q18), is this lab workbook directly associated with the text book?

Figure 10/Q57: Would you want pre-configured labs that map to your current textbook(s)?

<u>Commentary:</u> A summary of Figures 7 through 10 can be stated as: Faculty has primary responsibility for creating lab assignments. They are creative in defining labs that reflect their individual viewpoint on the learning objectives which benefit from hands-on experience. The lab assignments currently being created by a faculty are independent of text books. Text book publishers have an opportunity to provide pre-configured labs which map to the text. One likely reason that faculty has this unsatisfied desire/need is that it would reduce its work load.

It is interesting to note that many traditional science degree programs like biology, chemistry and physics segment lab activities into separate “credit” courses which generate fees and associated remuneration for a faculty participation in the lab setup and instruction process. In comparison, computer science degree programs do not often take this approach, and, consequently, computer science instructors often create and implement labs in their “free” time.

Figure 11/Q16: How frequently do laboratory assignments change in order to keep up with industry trends?

Figure 12/Q25: Are the labs updated when the course curriculum/text book edition changes?

<u>Commentary:</u> Only one school said “no” to this question. Comparison of the positive responses to this question with the negative responses in Figure 9 provides definite proof that faculty has a keen understanding of how its workload might be reduced if text book publishers facilitated content appropriate lab configurations.

Group 4 - Lab Management Responsibility

Figure 13/Q20: Is the IT department involved in the management of lab resources?

Figure 14/Q21: Who is responsible for the installation and maintenance of lab equipment?

Figure 15/Q22: Who is responsible for implementing initial, course-specific configurations?

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<u>Commentary:</u> Half of the respondents indicated the faculty is responsible for "implementing" lab configurations. Therefore, in addition to the design work identified in Figure 7, faculty frequently has the additional responsibility of implementation.

Figure 16/Q23: How far in advance must the new Lab Setup Request be submitted prior to the first day of classes?

<u>Commentary:</u> The answers presented in Figures 13, 14 and 16 identify a tension point between the faculty's desire to express intellectual freedom by using agile teaching methods and the reality of scheduling time lines dictated by the day-to-day events resulting from inter-departmental dependencies and interactions.

Figure 17/Q24: Who is responsible for implementing changes required by course curriculum updates?

<u>Commentary:</u> The answer is, once again, the faculty. Strong correlation here with the responses shown in Figures 7 and 12 provides support for the idea that the respondents approached the survey with professional diligence which resulted in accurate data.

Group 5 - Lab Technical Features

Figure 18/Q29: How many students can use the lab at the same time?

<u>Commentary:</u> One of the respondents indicated that hundreds of students can use the lab at the same time. Further investigation into this claim was conducted to determine what type of architecture was chosen to support this scale of operation. It turns out that this school has designed labs implemented as individual virtual machines which are downloaded onto student computers and run in personal computer hypervisors such as VMware Player or Oracle VirtualBox. Although this distributed approach does avoid the scaling issues which arise in a centralized environment, it has the downside of limiting the complexity of lab configurations to assignments which can be performed on one computer at a time.

Figure 19/Q30: How many computers can a single student be tasked to use in a single assignment?

Figure 20/Q31: Does your current lab support group collaboration?

<u>Commentary:</u> A majority of respondents said Yes to this question. However, not all of the positive answers represented the presence of a technological solution. For example, one school said that two students sharing a single desk/computer represented group collaboration and another school indicated that multiple students huddled around a computer was also a form of group collaboration. Only one school indicated that group collaboration was supported by a virtual lab accessible to both distance learners and on-site students.

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Figure 21/Q33: Does your current lab support team assignments in which multiple students can access the same machine?

Figure 22/Q35: Does your current lab support individual machines for each student as well as an additional group of machines?

Commentary: The responses to this question are indicative of the diverse innovation that creative instructors bring to the teaching profession. A majority of the schools have identified the benefits of providing students with both individual and group accessible machines. Even though the architectures vary significantly, it is important to note that this requirement is important to a majority of respondents.

Figure 23/Q36: Does your current lab support assignments which require multiple vLANs?

Commentary: The majority of labs did not support multiple vLANs. The primary reason for this limitation is the additional administrative effort; required to setup and maintain complex network environments. A faculty desires to teach students creative, real-world examples but is limited by time to setup such configurations. Support staff, likewise, has other priorities and is limited in its ability to customize complex topologies.

Group 6 - Hardware

Figure 24/Q40: What type of hardware is used in your lab?

Commentary: Toolwire[10] is a company which provides schools the ability to outsource their computer lab requirements on a contract basis.

Figure 25/Q41: What is the hardware refresh cycle?

Figure 26/Q42: What type of software is used in your lab?

Commentary: In addition to Open Source applications which were expected, several schools also mentioned Windows products were part of the lab(s). In future surveys, respondents will be given an opportunity to differentiate between desktop and server products.

Figure 27/Q43: What type of hardware and/or software is missing from your lab?

Commentary: Almost everyone was satisfied with their lab configurations.

Figure 28/Q46: Is your current laboratory limited in terms of Capital Expenses (expenses whose benefits are expected to carry over from one year to the next, such as hardware)?

Figure 29/Q55: Would you like to have labs with complex networks including multi-vLAN and WAN configurations?

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Commentary: Despite the satisfaction expressed in Figure 27, the answers in Figure 28 and 29 indicate that faculty continues to look for experiential learning environments which will enrich the student experience. Laboratory configurations with multi-vLAN network segments provide faculty with the opportunity to expose students to environments which closely resemble real world scenarios. This exposure is of particular importance in degree programs such as computer science which prepare students to enter the workforce with a strong set of technical skills.

Group 7 - Learning Management System Interface

Figure 30/Q38: How are lab assignments submitted by your students?

Commentary: Each school provided a different response. Some of the answers include: Screen shots, uploads to shared directories, Blackboard[14] and in person review.

Figure 31/Q39: Does your current lab software interface directly with your learning management system?

Commentary: None of the labs interfaced directly with the schools' learning management systems. Combined with the answers presented in Figure 30, this response indicates yet another burden faculty faces; the need to grade the results of lab activity without having any automated tools to aid in this task.

Figure 32/Q50: Is the PDF resource library a feature that adds value to the learning experience?

Figure 33/Q51: Is the multimedia library a feature that adds value to the learning experience?

Figure 34/Q52: Would a faculty in your department record videos for use in the lab assignments?

Figure 35/Q53: Would you allow your students to use the Chat function during lab assignments?

Commentary: The answers provided in Figures 32 through 35 reference features of iNetwork's Computer Lab as a Service (CLaaS) platform. Prior to taking the survey, respondents were to watch a five minute video which demonstrated the CLaaS platform's functionality.

Figure 36/Q58: Would you want the ability to review a recorded session of the student's lab activity?

Commentary: This question ties back to the information gathered in Figures 30 and 31. The idea behind this suggested function is to simplify a faculty's evaluation process by allowing her to visually observe the student's recorded activities while attempting to complete an assignment inside a virtual lab environment. A majority of respondents expressed interest in this function.

Graphical Survey Responses

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The graphical images presented in this section provide a visual method for analysis of the data collected in the survey reported on in this paper. The information is grouped in the same order as it was presented in the preceding section.

During the actual survey, additional questions which are not reported on in this paper were posed to the respondents. Also, the questions which are included in this paper were presented in a different order. The raw data has been scrubbed and then grouped to ensure accuracy and relevance.

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Group 1 - General Information

7. Annual Enrollment

	Response Percent	Response Count
<25	0.0%	0
25-50	50.0%	4
50-100	37.5%	3
100>	12.5%	1
answered question		8
skipped question		0

Figure 1

28. Can your students access the current lab remotely?

	Response Percent	Response Count
Yes	71.4%	5
No	28.6%	2
answered question		7
skipped question		1

Figure 2

Group 2 - Budgetary Information

Page 3, Q13. What is the annual departmental cost (budget) for lab equipment, maintenance agreements, and software license updates?

1	5000	Oct 23, 2014 5:00 PM
2	?	Oct 21, 2014 11:10 AM
3	Unknown.	Oct 20, 2014 7:53 AM
4	N/A	Oct 15, 2014 7:37 AM
5	don't know	Oct 14, 2014 5:26 PM
6	Approximately 5000 USD	Oct 14, 2014 12:51 PM
7	No idea	Oct 14, 2014 9:31 AM
8	Do Not Know	Oct 14, 2014 7:57 AM

Figure 3

14. How are lab costs tracked?

	Response Percent	Response Count
By course	37.5%	3
By class	0.0%	0
By student	0.0%	0
Other (please specify)	62.5%	5
answered question		8
skipped question		0

Figure 4

15. Do you charge students a "lab fee" for enrollment/use of lab resources?

	Response Percent	Response Count
Yes	50.0%	4
No	50.0%	4
answered question		8
skipped question		0

Figure 5

47. If you could implement new labs as an Operating Expense (in other words, as a day-to-day expense, such as administration costs, licensing costs, etc) would that enhance your instructional flexibility?

	Response Percent	Response Count
Yes	50.0%	3
No	50.0%	3
answered question		6
skipped question		2

Figure 6

Group 3 - Curriculum Learning Objectives

17. Who creates the lab assignments?

	Response Percent	Response Count
Professor	75.0%	6
Teaching Assistant(s)	12.5%	1
Author of text in use	0.0%	0
Other (please specify)	12.5%	1
answered question		8
skipped question		0

Figure 7

18. Do you have a separate lab workbook that contains course specific lab assignments?

	Response Percent	Response Count
Yes	37.5%	3
No	62.5%	5
answered question		8
skipped question		0

Figure 8

19. If yes, is this lab workbook directly associated with the text book?

	Response Percent	Response Count
Yes	12.5%	1
No	87.5%	7
answered question		8
skipped question		0

Figure 9

57. Would you want pre-configured labs that map to your current Pearson textbook(s)?

	Response Percent	Response Count
Yes	83.3%	5
No	16.7%	1
answered question		6
skipped question		2

Figure 10

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16. How frequently do laboratory assignments change in order to keep up with industry trends?	Response Percent	Response Count
Every semester	37.5%	3
Annually	25.0%	2
Bi-annually	12.5%	1
Other (please specify)	25.0%	2
answered question		8
skipped question		0

Figure 11

25. Are the labs updated when the course curriculum/text book edition changes?	Response Percent	Response Count
Yes	87.5%	7
No	12.5%	1
answered question		8
skipped question		0

Figure 12

Group 4 - Lab Management Responsibility

20. Is the IT department involved in the management of lab resources?	Response Percent	Response Count
Yes	50.0%	4
No	50.0%	4
answered question		8
skipped question		0

Figure 13

21. Who is responsible for installation and maintenance of lab equipment?	Response Percent	Response Count
IT Support	37.5%	3
Computer Science department	0.0%	0
Other (please specify)	62.5%	5
answered question		8
skipped question		0

Figure 14

22. Who is responsible for implementing initial, course-specific configurations?	Response Percent	Response Count
IT Support	37.5%	3
Computer Science department	0.0%	0
Professor	50.0%	4
Teaching Assistant(s)	0.0%	0
Other (please specify)	12.5%	1
answered question		8
skipped question		0

Figure 15

23. How far in advance must the New Lab Setup Request be submitted prior to the first day of class?	Response Percent	Response Count
Weeks	37.5%	3
Months	37.5%	3
One semester	0.0%	0
Other (please specify)	25.0%	2
answered question		8
skipped question		0

Figure 16

24. Who is responsible for implementing changes required by course curriculum updates?	Response Percent	Response Count
IT Support	0.0%	0
Computer Science department	0.0%	0
Professor	87.5%	7
Teaching Assistant(s)	0.0%	0
Other (please specify)	12.5%	1
answered question		8
skipped question		0

Figure 17

Group 5 - Lab Features

Page 5, Q29. How many students can use the lab at the same time?		
1	24	Oct 23, 2014 5:04 PM
2	?	Oct 21, 2014 11:11 AM
3	50	Oct 20, 2014 7:55 AM
4	hundreds	Oct 15, 2014 7:43 AM
5	20	Oct 14, 2014 12:56 PM
6	No idea	Oct 14, 2014 9:34 AM
7	16	Oct 14, 2014 8:01 AM

Figure 18

30. How many computers can a single student be tasked to use in a single assignment?	Response Percent	Response Count
1	42.9%	3
2	14.3%	1
3	0.0%	0
4	0.0%	0
5	0.0%	0
Other (please specify)	42.9%	3
answered question		7
skipped question		1

Figure 19

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31. Does your current lab support group collaboration?

	Response Percent	Response Count
Yes	57.1%	4
No	42.9%	3
answered question		7
skipped question		1

Figure 20

33. Does your current lab support team assignments in which multiple students can access the same machine(s)?

	Response Percent	Response Count
Yes	71.4%	5
No	28.6%	2
answered question		7
skipped question		1

Figure 21

35. Does your current lab support individual machines for each student as well as an additional group of machines available for shared used by all the students in the class?

	Response Percent	Response Count
Yes	71.4%	5
No	14.3%	1
Other (please specify)	14.3%	1
answered question		7
skipped question		1

Figure 22

36. Does your current lab support assignments which require multiple VLANs?

	Response Percent	Response Count
Yes	42.9%	3
No	57.1%	4
answered question		7
skipped question		1

Figure 23

Group 6 - Hardware

Page 5, Q40. What type of hardware is used in your lab?

1	multiple	Oct 23, 2014 5:04 PM
2	?	Oct 21, 2014 11:11 AM
3	Standard PCS	Oct 20, 2014 7:55 AM
4	Dell high performance servers	Oct 15, 2014 7:43 AM
5	Desktop computers	Oct 14, 2014 12:56 PM
6	You'd need to ask Toolwire	Oct 14, 2014 9:34 AM
7	Computers with Virtual Machines	Oct 14, 2014 8:01 AM

Figure 24

41. What is the hardware refresh cycle?

	Response Percent	Response Count
Annually	0.0%	0
Biannually	0.0%	0
Every 3-5 years	71.4%	5
5+ years	0.0%	0
Other (please specify)	28.6%	2
answered question		7
skipped question		1

Figure 25

Page 5, Q42. What type of software is used in your lab?

1	windows, linux, forensics tools, open source	Oct 23, 2014 5:04 PM
2	There is no "current lab".	Oct 21, 2014 11:11 AM
3	Standard linux distribution + scientific packages	Oct 20, 2014 7:55 AM
4	Linux, Windows, Kali Linux, Security Onion, phSense, WordPress, keylogger, superscan, etc.	Oct 15, 2014 7:43 AM
5	Linux OS for host, virtual boxes for guest Windows/Linux	Oct 14, 2014 12:56 PM
6	Again, you'd need to ask Toolwire	Oct 14, 2014 9:34 AM
7	Windows, Linux	Oct 14, 2014 8:01 AM

Figure 26

Page 5, Q43. What type of hardware and/or software is missing from your lab?

1	too difficult to say	Oct 23, 2014 5:04 PM
2	There is no "current lab".	Oct 21, 2014 11:11 AM
3	N/A	Oct 20, 2014 7:55 AM
4	N/A	Oct 15, 2014 7:43 AM
5	None that is required for the course	Oct 14, 2014 12:56 PM
6	None that I know of	Oct 14, 2014 9:34 AM
7	Network analysis tools and software	Oct 14, 2014 8:01 AM

Figure 27

46. Is your current laboratory limited in terms of Capital Expenses (expenses whose benefits are expected to carry over from one year to the next, such as hardware)?

	Response Percent	Response Count
Yes	66.7%	4
No	33.3%	2
answered question		6
skipped question		2

Figure 28

55. Would you like to have labs with complex networks including multi-VLAN and WAN configurations?

	Response Percent	Response Count
Yes	83.3%	5
No	16.7%	1
answered question		6
skipped question		2

Figure 29

Group 7 - Learning Mgmt System Interface

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Page 5, Q38. How are lab assignments submitted by your students?		
1	varies	Oct 23, 2014 5:04 PM
2	There are no current labs.	Oct 21, 2014 11:11 AM
3	Electronically	Oct 20, 2014 7:55 AM
4	via Blackboard	Oct 15, 2014 7:43 AM
5	They put it in a shared directory accessible by the TAs through the server.	Oct 14, 2014 12:56 PM
6	Screenshots of crucial steps along with explanatory statements	Oct 14, 2014 9:34 AM
7	In person review	Oct 14, 2014 8:01 AM

Figure 30

39. Does the current lab software interface directly with your Learning Management System?

	Response Percent	Response Count
Yes	0.0%	0
No	100.0%	7
answered question		7
skipped question		1

Figure 31

50. Is the PDF resource library a feature that adds value to the learning experience?

	Response Percent	Response Count
Yes	83.3%	5
No	16.7%	1
answered question		6
skipped question		2

Figure 32

51. Is the multimedia library a feature that adds value to the learning experience?

	Response Percent	Response Count
Yes	83.3%	5
No	16.7%	1
answered question		6
skipped question		2

Figure 33

52. Would professors in your department record their own videos for use in the lab assignments?

	Response Percent	Response Count
Yes	50.0%	3
No	50.0%	3
answered question		6
skipped question		2

Figure 34

53. Would you allow your students to use the Chat function during lab assignments?

	Response Percent	Response Count
Yes	83.3%	5
No	16.7%	1
answered question		6
skipped question		2

Figure 35

58. Would you want the ability to review a recorded session of the student's lab activity?

	Response Percent	Response Count
Yes	83.3%	5
No	16.7%	1
answered question		6
skipped question		2

Figure 36

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Investigative Research

In the process of preparing the survey questions, the authors researched prior art on the topics of virtual computer lab provisioning and distance learning. The paragraphs which follow present a number of the findings.

This paper reviews data collected during a survey designed to identify elements that play an important role in the decision making process used by schools to determine how to provision computer science laboratories. One underlying assumption was that the results would be useful in determining if a large percentage of distance learners can participate in hands-on, experiential computer labs. Another assumption was that if distance learners did in fact have the opportunity to participate, the labs would virtual labs, accessible via the internet.

The earliest reference the authors found to these concepts dates to 1990 when Joyce presented a paper describing a virtual lab to support introductory courses in computer science[3]. One of the authors, Romney, implemented, in 2004, a virtual lab for teaching information security concepts[11] as Hill et. al. had shown that "security is learned by doing.[12]" In 2011, Cavanagh and Albert defined a virtual lab as "a facility that provides a remotely accessible environment to conduct hands-on experimental work and research information security[4]". However, it is obvious not to limit the concept of virtual labs to the realm of information security, but, rather, extend such technology to all of computer science. In an update to their original paper, Cavanagh and Albert reported that the provisioning of the Maine Information Security Lab (MEISLab) required secure access by students enrolled in distance education programs[5].

Beginning in 2004, papers began to describe virtual lab designs implemented using virtualization technology such as Virtual PC[11] and VMware. It required four years of petitioning VMware, citing the Digital Equipment Corporation model, before VMware agreed to offer an educationally attractive licensing module for use of its hypervisor in such university virtual lab configurations[13].

One recurring theme in these papers was the lack of funding available to pay for the continual upgrades required to keep up with rapidly evolving hardware and software. For example, in a discussion of the benefits thin-client technology brings to computer labs designed for distance learners, Martinez stated that "some institutions do not even have computer labs due to unaffordable costs[6]. Another finding on this topic was "Virtualized lab infrastructure on a budget for various computing and engineering courses" which Guler et. al. presented at the 2012 ITHET conference[7].

Several recent papers discuss the architecture and benefits associated with provisioning of Cloud-based computer labs. In the paper entitled "CloudWhip: A Tool for Provisioning Cyber Security Labs in the Amazon Cloud", Amorin, Shekar, and AlAufi compare the provisioning requirements of an in-house lab with one implemented in the Cloud and come to the conclusion that a cloud based lab will result in significant cost reductions[8]. Additionally, Ali and El-Ghareeb in their paper "Implementation of Cloud-based Virtual Labs for Educational Purposes"[9] describe a design which combines Infrastructure as a Service, Platform as a Service and Software

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as a Service components into an educational system very similar to iNetwork's Computer Lab as a Service (CLaaS) platform.

Survey Results

Group 1 – General Information

The survey reveals that seventy-one (71) percent of the schools provide students with remote access to computer science labs. The authors believe that two conclusions can be made from these data:

1) Distance learners desiring to study computer science will have no problem locating schools which have an experiential learning component as part of the degree program.
2) A significant number of schools have still not made the link between potential enrollment of students in on-line computer science programs and the need to provide an experiential learning component as part of the on-line degree program.

Group 2 – Budgetary Information

The survey reveals that most faculty do not know how much their schools budget for the provisioning of computer science labs. The limited numbers which were reported seem very low. If they are in fact correct, this would indicate that these schools are not adequately investing in their computer science programs. It was interesting to learn that fifty percent of the schools charge their students lab fees and also that fifty percent of the faculty believe outsourcing the computer science lab function would enhance their computer science program.

Group 3 - Curriculum Learning Objectives

The survey reveals that most schools expect faculty to create lab assignments. It also reveals that very few schools use labs which are directly associated with the text book. One reason for the lack of correlation between text books and lab assignments is that many computer science text books do not have a corresponding lab workbook. The survey also reveals that faculty would like the text book publishers to offer this service.

Group 4 – Lab Management Responsibility

The survey reveals that in fifty percent of the schools, the IT department is involved in the management of the computer science lab. However, this percentage decreases to thirty-seven percent when looking at lab maintenance, support and course specific configurations. Incredibly, the IT department is never involved (zero percent) in the implementation of configuration changes required for course curriculum updates.

Group 5 – Lab Technical Features

The wide variance in the number of students who can use the lab at the same time (16, 20, 24, 50, hundreds) is indicative of design variance, architecture selection and funding levels. Forty-

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two percent of the schools provision labs with a single computer for each student. Fourteen percent of the schools make two machines available for each student.

Seventy-one percent of the computer science labs support group assignments in which multiple students can share the same machines. These schools' labs are also provisioned with enough equipment so that dedicated student machines are available in addition to the resources shared by the student group(s). Only forty-two percent of the labs are provisioned with the equipment to support lab assignments which require multiple vLANs.

Group 6 – Hardware

The survey reveals a broad range of hardware. Responses include desktops, high performance Dell servers, virtualized infrastructures and outsourced, internet accessible solutions. This response supports the findings reported in the Lab Technical Features group and indicates that each school has implemented its computer science lab independently, using whatever resources were available at the time. Seventy-one percent of the schools reported that the hardware refresh cycle was three to five years. None of the schools indicated that their labs were missing critical equipment. On the other hand, sixty-six percent of the schools reported that their labs were limited by capital expense budgets.

Eight-three percent of the schools reported that they would like labs which were provisioned to support multi-vLAN and WAN configurations. As reported in Lab Technical Features (Group 5) only 42 percent of the labs currently support multiple vLANs. Therefore, although no schools reported a lack of critical equipment these two responses indicated an unmet desire to provide students with access to more complex and challenging environments.

Group 7 – Learning Management System Interface

None of the computer science labs had a direct interface with the schools' Learning Management System(s). Eighty-three percent of the respondents felt that a PDF resource library and a multi-media library would be useful features in a computer science lab. Fifty percent of the schools indicated that faculty would use the multi-media library and record their own video clips to go along with lab assignments.

Eighty-three percent of the schools indicated that they would allow students to collaborate using a chat function during lab assignments. These same schools also indicated that they would like the capability to review recorded sessions of students' on-screen actions during the lab assignment.

Conclusion

This paper presents evidence that the responsibility for computer science labs falls primarily on the faculty. The survey results indicate that the schools' IT departments are involved in lab provisioning, however, the results did not indicate that the IT department shoulders the burdens associated with the on-going maintenance and configuration updates required to keep the

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curriculum relevant. These tasks fall to the faculty who likely face difficult decisions in the prioritization and allocation of their time on a daily basis. The survey clearly reveals that instructors are interested in access to labs provisioned to be closely aligned with textbooks.

The survey results indicate that computer science labs have been implemented with a wide variety of designs, equipment and capabilities. Our research revealed that many labs were cobbled together by dedicated faculty using surplus equipment and limited funds. Given the fundamental importance of experiential education in computer science education, it is evident that prospective students will be well-served by evaluating and comparing universities before selecting a computer science degree program.

The authors posit that schools should a) actively involve faculties to define requirements for new investment in computer science labs, b) invest in a computer lab manager to remove virtual asset configuration deployment from the faculties, and c) provision support for distance learners to better accommodate changing trends in social behavior and associated mobile technologies.

Recommendations for Future Research

The authors plan to expand the data set presented in this paper to include a much larger number of respondents. The current working concept is to contact the 181 schools designated as National Security Agency (NSA) and Department of Homeland Security (DHS) Centers of Academic Excellence requesting their participation. Increasing the number of respondents upward toward 100 in number would allow a more statistically valid analysis.

Acknowledgements

The authors wish to thank the editors and staff of the Pearson Education Computer Science division for their assistance in identifying survey participants and support of the survey process.

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Using the Mastering Engineering Homework Online Tool in the Circuits Course: Advantages and Shortcomings

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Abstract

In an era where countless debates are taking place about new ways the digital-native generation of students learn and grow, techniques such as online homework tools are being offered by several editors, and have been improved throughout the last few years to best serve problem solving skills and improve students learning outcomes. In this study, we used the Pearson *Mastering Engineering* homework online tool in the electrical circuits' class as a trial in the homework that covers the RL/RC natural, step response, and sequential switching, which is one of the most challenging parts of the circuits' course. Students' performance in the homework was monitored and a survey was administered to get students' feedback on using the *Mastering Engineering* tool. The final exam included one problem on RC switching, and performance was correlated to the results of the homework.

Background/Introduction

Homework is a critical part of college education. It is the primary tool to enforce the learning taken in class. Instructors spend a big portion of their time creating new homework and writing their solutions. For effectiveness, homework assignments usually have to be updated every semester to avoid having students use old posted solutions. Nevertheless, many students find ways to cheat using solutions provided by sites such as *CourseHero,* or *Cramster* [1]. The good grades in homework give them the false impression that they are performing well in the class, until the exams come, and many are deceived. Instructors have long struggled to find ways to make students learn in a more efficient way, and homework remains a big dilemma suggesting that its practices should change. New teaching styles have been blossoming during the last few years, such as the flipped classroom where homework is no longer a work done at home[2]. There are however arguments about potential disadvantages of such pedagogy [3]. With the spread of the internet came homework online tools, such as WebAssign a tool created by Dr. Risley of the University of North Carolina in 1997 [4] and WeBWorK an open source online homework system [5]. While not very common in Engineering, online homework tools have now been used by instructors for over a decade, especially in math, physics, and chemistry classes [6,

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7]. There are several reasons why these online tools are attractive: First, they save grading time, a hard-to-resist quality especially for large classes. Second, they provide immediate feedback to students, unlike in the case of paper homework where they have to wait at least a week before they get a chance to know what they did wrong; which in most cases comes at a time students are already dealing with new concepts in class. Online tools can also allow students to end up getting a high homework grade if they are given several chances to enter their results online. Third, the problems' variables being changed for each individual, allow less chances for them to copy from their peers. In this study, we test "Mastering Engineering" (ME), the Pearson online homework tool in an electrical Circuits class for homework dealing with the sequential switching in RL, and RC circuits, a part of the course that is historically known to be troublesome to most students. Grades were recorded and compared later with the scores on an RC switching problem in the final exam.

Experiment

After covering the chapter dealing with step response of RL and RC circuits and solving related circuits with sequential switching (2 or 3 switches open at specific times which changes the circuit response at each of the switching, and the question usually asks to find the expression of current or voltage as a function of time) The *Mastering Engineering* tool settings can be adjusted by the instructor. For instance the number of times allowed for responses. There is also a deduction of points if the student asks for hints to answer the question. Each student gets different numbers, and even problems are not in the same order, which leaves very little space for copying from peers. In order to eliminate any effects of instructor or peer pressure (or impression of pressure) on students, the responses were made completely anonymous. We used surveymonkey.com to collect the data.

The following are the questions students had to answer:

1- How prepared did you feel when starting your homework using the Mastering Engineering tool?
2- How easy was it to use mastering engineering to solve circuit problems (compared to paper homework)?
3- How clearly did Mastering Engineering present the problems/questions?
4- How much did the Mastering Engineering tool help you develop critical thinking skills?
5- How helpful were the hints provided in Mastering Engineering (if you used them)?
6- How effective was Mastering Engineering in teaching you more about RC/RL switching (in other words did you feel you improved your understanding of the material?)
7- Based on your experience using it, what are in your view the greatest strengths (if any) of Mastering Engineering?

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8- Please describe the greatest weaknesses (if any) of Mastering Engineering.
9- If you were given the choice, would you have chosen Mastering engineering as your homework tool in this class?

For question 1 thru 6, students were supposed to choose a rating of 1, 2, 3, 4, or 5. While for questions 7 and 8 students were asked to narrate their opinion in a few lines. Finally question 9 had 4 options for answers: “Definitely yes”, “Maybe”, Neutral, “I would prefer to avoid”, and “No! please no!”. A total of 32 students participated in the study.

Results and Discussion

Figure 1 shows students previous familiarity with the Mastering Engineering tool. 27 out of 32 students felt at least somehow familiar with the tool. The reason being because the physics class that is the prerequisite for circuits uses a similar tool called “Mastering Physics”. Figure 2 shows students’ rating on how easy it was to use the Mastering Engineering tool. Contrary to the familiarity with the tool (~84%), the easiness of use was not evident. About 50% of students rated it at 2 or less.

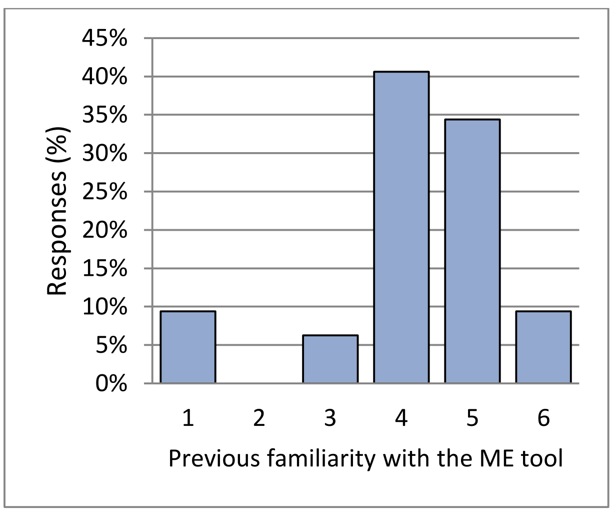

Fig. 1. Previous familiarity with the online homework tool used.

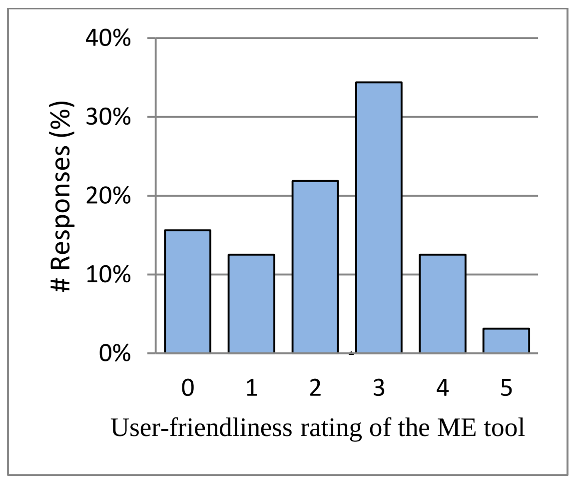

Fig. 2. Easiness of using Mastering Engineering.

Figure 3 shows students’ rating of the clarity of questions presented in the homework. As expected, this graph slightly matches the graph depicting the easiness of the tool (the clarity of questions affects students perception of easiness of using the tool). When asked about the major advantages in using Mastering Engineering, the top answer (~28%) indicated the “instant feedback” feature of the tool (Table 1). That is no surprise since students are usually frustrated when they can’t see their copies (and the homework solution) soon after the homework. They like to know what went wrong right away; specifically when exams get close. The ME tool also offers students hints to answer questions if they ask for help. About

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22% of them rated the hints to be a major advantage, while 19% liked the step-by-step guidance in answering questions. Only 9.4% thought the tool was good because it prevented students from cheating. Figure 4 shows students' rating of critical thinking. Over 68% believe that the ME tool pushed them to think critically. While we have not compared this rating with ratings they would have given about a regular pencil and paper homework, we can assume that the student, being alone in front of a screen is better isolated to think critically, as opposed to traditional ways where students often stop to ask a peer about a problem, instead of trying to solve it all alone. Hints were appreciated by most students, but about 20% of them thought that hints were useless or had very little value (rating of 0 or 1 in Fig. 5), probably due to a lack of clarity.

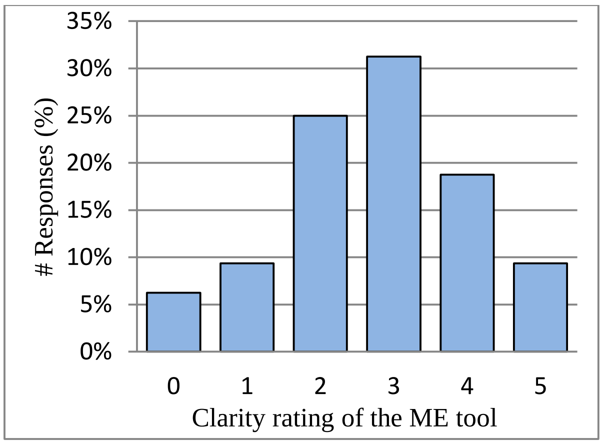

Fig. 3. Clarity of question in ME.

Advantages of using ME	% Responses
Instant feedback	28.13%
Hints	21.88%
step by step guidance	18.75%
None	12.50%
No cheating	9.38%
other	9.38%

Table 1: Advantages of using the ME tool.

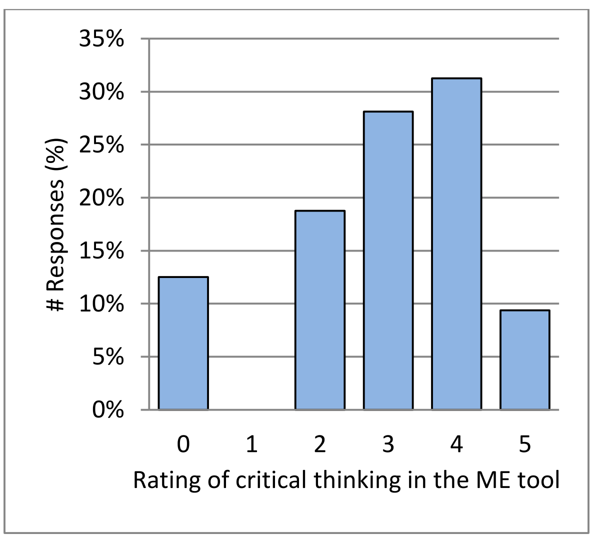

Fig. 4. Students' assessment of critical thinking in the ME tool

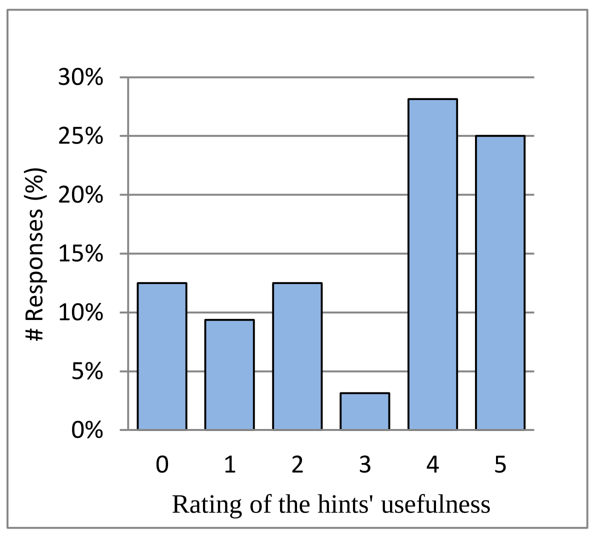

Fig. 5. Ratings of the "hints" feature help.

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Table 2 shows the major weakness of the ME tool listed by students. The total percentage is greater than a 100% because few participants provided two or more weaknesses. The major issue listed by 40% of students is related to inputting the answers. Sometimes the answer is right, but the user may use an additional decimal or enter the wrong symbol for a unit. The ME tool only accepts the answer as programmed by the homework designers. This is in our view a big issue, and the origin of all frustration observed among students when they came to seek help during office hours. Finally, when asked if they would be interested in using the ME homework tool in the future, over 59% did not reject the idea versus the 41% who would rather not deal with it.

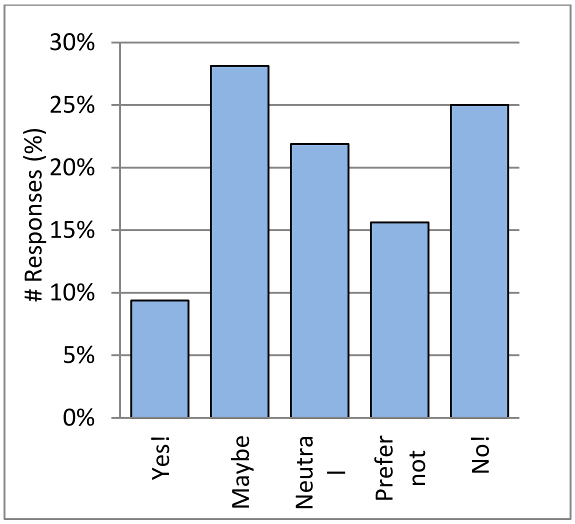
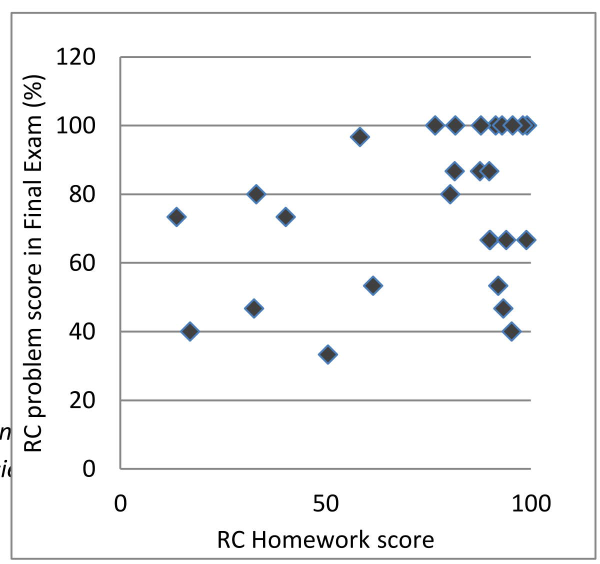


Fig. 6. Students opinion on using the ME homework tool in the future.

Weakness	Responses
Issues with inputting the answers	40.63%
Time consuming	18.75%
Unclear in general	12.50%
No partial credit	9.38%
Points deduction for trying	9.38%
Not user friendly	6.25%
None	6.25%
No advice received (what did I do wrong?)	6.25%
Everything	6.25%

Table 2: Major weaknesses of the ME tool.

We wanted to look for any correlation of the homework results to the results obtained in the final exam. Figure 7 shows the scores obtained in the final exam versus the average score of all homework assignments (paper and pencil type), while Figure 8 shows the score of the problem in the final exam specifically covering RC circuits, versus the homework # 6 scores (the one done online). In both figures we see little correlation between homework and exam. However, there is a small number of students (7) who scored high (above 85%) in the homework and below 65% in the corresponding problem in the final, which usually happens when using regular homework.



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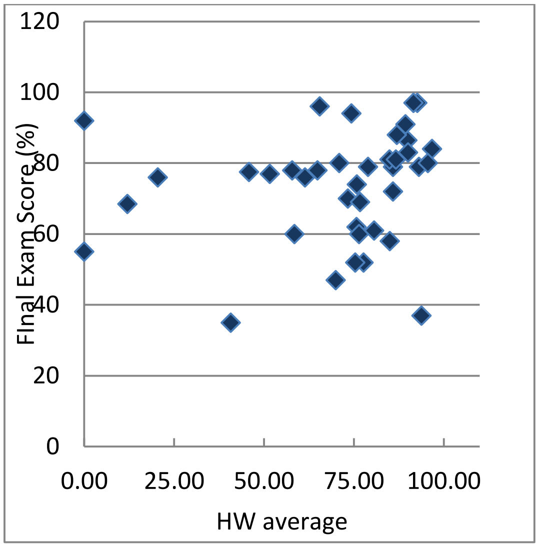

Fig. 7. Final exam scores vs. total homework average

Fig. 8. Scores of the RC problem in the final exam versus homework 6 scores. HW 6 (RC) was done using the Mastering Engineering tool.

Conclusion

We tried *Mastering Engineering*, an online homework tool, for the first time in our circuits' course by targeting the RL/RC natural, step response, and sequential switching. Students' feedback was collected and analyzed and their performance tracked in the final exam. The tool has several advantages such as the instant feedback, the hints and the individualized character that prevents cheating. While some of the disadvantages included the difficulty in using the tool, specifically inputting results, or typing complex formulas. The correlation to results in the final exam was not much different than the case of paper and pencil homework. There was a slight irritation of most students with using this tool, but majority of them didn't reject the idea of using it in future classes. A longer term use of this tool, with a larger data might lead to further findings.

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Design of an Assembly for a Manufacturing Processes Laboratory

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Abstract

Presented is a mechanical assembly design which is used as the core product in a manufacturing processes course. The product design was developed to integrate mostly machining processes that are conducted throughout the semester. The product, a bench vise, had design criteria that were imposed primarily a result of educational needs and constraints at the institution, Northern Arizona University. These criteria included generous dimensional tolerances, constrained component dimensional sizes, use of a variety of materials, time-constrained process limits, and use of some commercial off-the-shelf parts in the assembly. Additionally, the laboratory is considered small by most accredited universities in the United States, with very limited personnel and equipment resources. In the context of these design needs and constraints, a bench vise design was created and the operations divided amongst the laboratories. Presented is the basic design plus modifications implemented and/or planned after two semesters and six sections of the laboratory offering. Limited student evaluations and anecdotes are also noted.

Introduction

Northern Arizona University (NAU) one of four Arizona universities offering undergraduate engineering programs; it is the smallest in the context of regular faculty appointments to the Mechanical Engineering program (10 tenure-track and lecturers). However, the NAU Mechanical Engineering undergraduate program can nearly match any campus for on-campus undergraduate Mechanical Engineering enrollment, approaching 800 students as of 2015. In this century, the faculty at NAU has seen a swell of enrollment in Mechanical Engineering—one data point is the 390% increase in enrollment since 2008. The result is both a challenge and an opportunity for this department to offer more a industrial-oriented manufacturing laboratory to the undergraduates.

Since the mid-1990's the NAU Engineering programs offer the "Design4Practice," or "D4P," curriculum, a series of innovative undergraduate classes which involve team-oriented learning classes for the students in each of their freshman, sophomore, junior and senior years. The D4P courses engaged students to learn by actively using engineering education tools that address the issues of realizing a design: problem solving, project management, and teaming.

The D4P program provided courses that emphasized team-oriented design and project management. However, traditional manufacturing knowledge and basic skills were not originally addressed, because the program, prior to the 2000's was not sufficiently large to generate sufficient resources to support an ongoing manufacturing laboratory. With the advent of increased enrollments and more flexible program fee expenditure spending policies, a manufacturing laboratory was possible.

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The Mechanical Engineering laboratory, ME 467L, was initially offered in 2004 as a purely process-demonstration laboratory. Students conducted operations and measurements for unconnected processes of milling, turning, welding, sheet metal forming, and polymer forming processes. The laboratory was offered with typically less than 20 students in a section as part of an elective Manufacturing Processes lecture. As enrollments increased in the program, the laboratory was re-designated as a separate offering from the lecture and optional—a student could enroll in the lecture for 3 hours of credit and choose not to enroll in the additional 1 credit hour (3 calendar hours) of laboratory. The lecture/lab combination was only offered every other year, as was typical for most ME electives in the small programs. Enrollments continued to swell to the point that an ongoing, *annual* lecture/lab could be offered starting in 2013. With an ongoing annual offering, the author considered a more product-realization experience for the manufacturing lab than was historically presented.

Other universities have shown a similar emphasis, from a curriculum-wide emphasis of design and manufacturing to a constrained laboratory experience where the manufacturing component is present to support the overall design emphasis of the class. An example of the latter was offered by the U.S. Coast Guard Academy. They incorporate a manufacturing lab component to their sophomore design class, through the construction of a small "air engine."[1] This mixed design/manufacture model was initially considered a good model for NAU and the sophomore D4P design course. However, separation between the design classroom and manufacturing facility locations at NAU eventually dictated that merging the two contexts into a single offering would be logistically difficult.

The Learning Factory concept is an example of comprehensive implementation.[2] Developed jointly by Pennsylvania State University, the University of Washington, and the University of Puerto Rico-Mayaguez, the manufacturing laboratories offered were in the context of an overall practice-based engineering curriculum that incorporated collaboration with industry and fully developed laboratories. This curriculum may be considered ideal for a design and manufacturing-oriented program. It was developed with comprehensive resource support through grants from the National Science Foundation (NSF), Sandia National Laboratories, and the federal Technology Reinvestment Program. The Learning Factory model was considered well-conceived and successful, as evidenced by its implementation in the engineering curricula of a number of additional universities, including University of Missouri-Columbia, and Marquette University.[3]

Recognizing the limited resources of intuitions that are not as fully supported through research and educational grants, a group of institutions, led by Wayne State University, adapted the Learning Factory Model in a flexible manner to each of the institutions' separate needs.[4,5] Each of the participating institutions addressed their particular core course-level learning outcomes that required improvement, adapting a portion of the educational pedagogy appropriately. NAU chose to adapt this philosophy for their needs in a new manufacturing laboratory experience that supported the existing engineering design product realization curricula.
Thus, once a product-oriented manufacturing process laboratory was selected, a product must be developed for the offering. For simplicity in discussion, the product will be introduced prior to the design discussion: A bench vise, the original 2013 design of which is shown in Figure 1.

Design Objectives and Constraints

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There were several design objectives and constraints identified for the lab product.

- Must accommodate existing equipment
- Constrained dimensions
- Variety of materials
- Incorporate Commercial-Off-The-Shelf (COTS) components
- Incorporate flexible operations

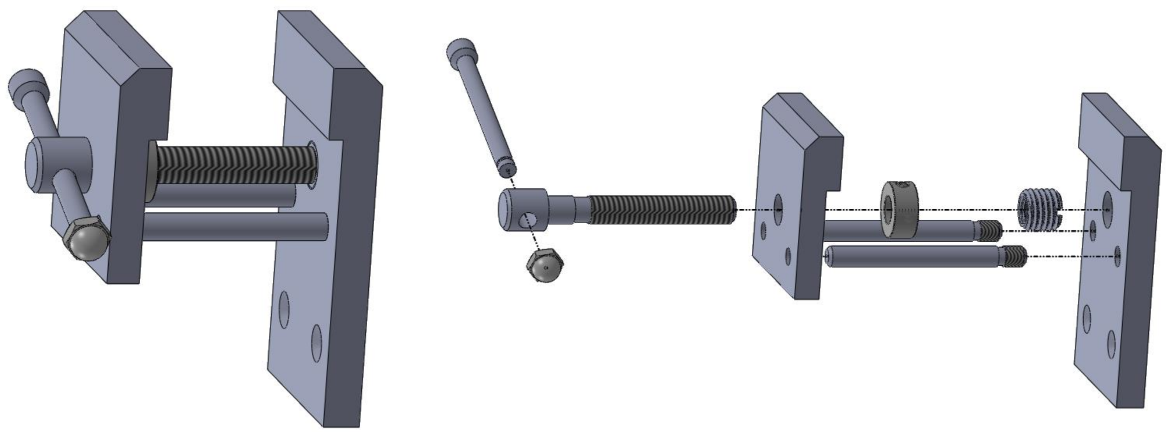

Figure 1. SolidWorks™ assembled (right) and exploded (left) views of 2013 Bench Vise assembly.

Existing equipment

The laboratory was developed over several years and modified as new equipment was acquired and installed. Initially, however, the equipment was old and worn. The original equipment consisted of very old lathes and mills, some of which were at last 65 years old. Though extremely reliable, these machines simply were too worn to hold linear accuracies beyond 0.010 inch in any axis. Originally, the laboratory developer wished to create small Stirling or air engines, as noted by other universities.[1] However, the required tolerances for such assemblies were not possible for the original NAU equipment. The new product must be robustly designed with generous dimensional tolerances.

The generous dimensional tolerance parameter also was supported for another reason: Laboratory students were assumed to have little to no knowledge of how to operate any manufacturing equipment. Consequently, the products they produced from the labs would inevitably have production errors. Designing a product with generous tolerances would increase the student's chance of producing a functional product with little experience on his or her part.

Constrained Dimensions

This constraint is tied closely to the issue of existing equipment but also due to limited floor space. The smallest mill initially used had an X by Y envelope of only 12 by 6 inches, respectively. Components for the product must be made from raw stock and its required setup fixtures that would

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fit within that envelope. In addition, there was limited space to store the work in process (WIP) for each week's lab from each student group. Thus, a small device was necessary for the laboratory focus. The bench vise fit that bill nicely; as of 2014, all three sections' WIP could be tagged and stored on a single rolling cart. There was some preparation fabrication required prior to the start of the semester class start, in order to make the in-semester laboratory activities manageable. For example, the vise's jaws raw aluminum bar stock was delivered with dimensions of 1 inch by 6 inch by 12 feet. Similarly, the brass guide pin rods stock was 12 feet in length, as was the steel main screw stock. All these long pieces needed to be preprocessed by the instructor and shop personnel prior to the start of the laboratory, so that storage and movement of the stock was not a problem in the confined spaces for the laboratory offering.

Variety of Materials

The vise could be made entirely of steel if desired. However, the instructor wished to give the students exposure to cutting and assembling with other types of materials. Also, using aluminum and brass would allow novice students a minimum of reliance on coolants during cutting processes. By minimizing coolant flow in a process, the student could more readily observe chip formation.

The welding of steel was offered in 2013 as a stand-alone, process-oriented laboratory. The welding process was thus not integrated into the product design context of that year's laboratory. In 2014 a "jaw cap" was implemented for a functional product design reason of protecting the aluminum jaw face from marring during use. The redesigned vise is shown in Figure 2. This jaw cap could have been easily redesigned and cut from angle stock. However, by assembling the jaw cap from two separate pieces of strap steel, the instructor is allowed to expose the students to the welding process as part of the product realization process, and also incorporate shearing, punching, and grinding.

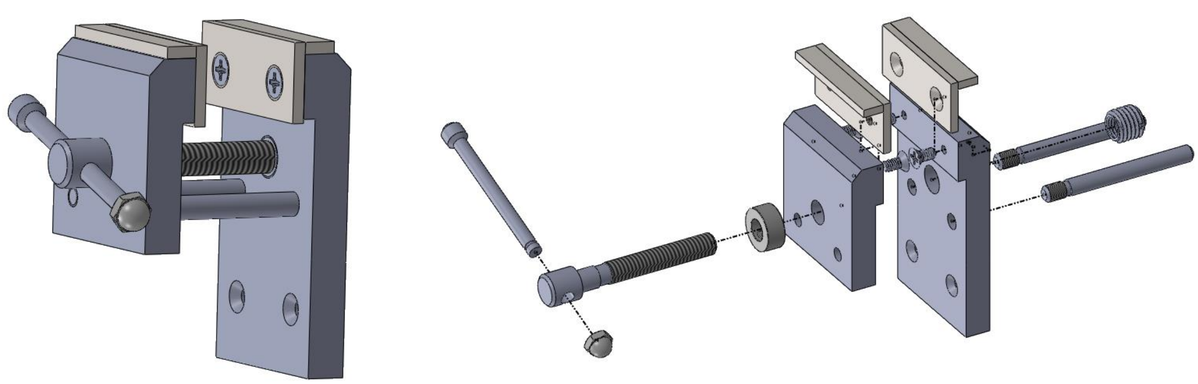

Figure 2. The 2014 redesigned Bench Vise.

COTS

The selection of an aluminum stock for the vise jaws results in an initial and undesirable choice of having a steel main screw being engaged in aluminum threading. Thus, a steel threaded insert was selected to be assembled into the vise jaw; this fixed insert then receives the steel main screw to eliminate the concern of stripping otherwise aluminum threads. A related benefit of this insert selection: Students engaged in learning manufacturing processes may become convinced that engineers must fabricate all parts in an assembly. In reality, much of product realization in engineering requires specifying retail components, or COTs parts. Sourcing this insert for the assembly, along with the use of machine screws for the jaw caps assembly and an acorn nut for the handle end, helps give the student a broader view of product design.

Figure 3 shows a photo of the 2014 lab product, with the use of multiple materials: Aluminum, brass, and steel. Additionally, this photo shows the COTS components of ½-20 flat-head machine screws and one 3/8-16 acorn nut. Not visible in the Figure 3 photo is one of the COTS components which is visible in Figure 1: a 1/2" bore, set screw Collar.

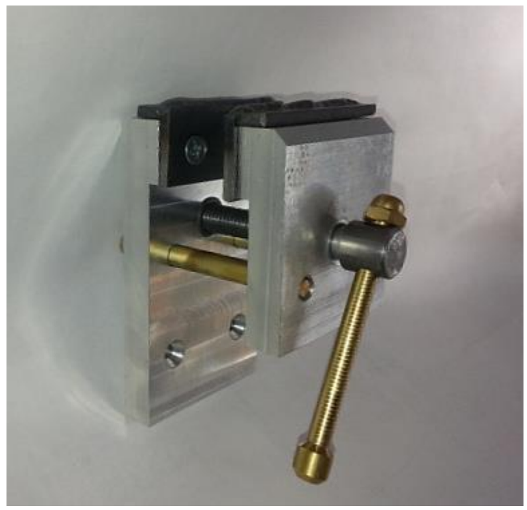

Figure 3. Final product: Multiple materials and COTS components all shown.

Flexible operations

Three laboratory sections could be offered in a semester. A facility layout (illustrated in Figure 4) was developed whereby four separate processing stations could be run simultaneously in a lab session, given sufficient supervision. By engaging as many machines simultaneously as possible in a given laboratory section's offering per week, the enrollment was allowed to be increased to as many as 24 students per lab. This approach does require knowledgeable student lab assistants to be hired in order to ensure all enrolled students are safely and appropriately monitored.

The product fabrication process required the manufacturing operations to be subdivided and setups established such that at least a few components could be processed in operations without a required sequence. The acquisition of CNC mills and lathes in 2013 aided in this endeavor. The two jaw components, the short jaw and the long jaw, were processed from raw stock in 2 basic processes on either a manual mill or a CNC mill. Squaring, facing, and drilling was accomplished on the manual mills. Edging (squaring of a datum edge), drilling, form milling and chamfering was accomplished on the CNC mills. By using two alternative CNC programs for the first CNC process, a student team could begin on a manual mill and finish the processes on the CNC mills, or vice-versa. This process enabled the manual mills and CNC mills to be run in the same lab by two different student groups; they would then swap to the other mills they had not used in a subsequent week, resulting in the same jaw components at the end of the swap.

In simple fact, these jaw components could have been made completely on the CNC mills in two setups, without the use of manual mills. However, as this was a lab of manufacturing process learning, the instructor wanted the students to experience milling (and lathe) processes in both basic manual and CNC environments.

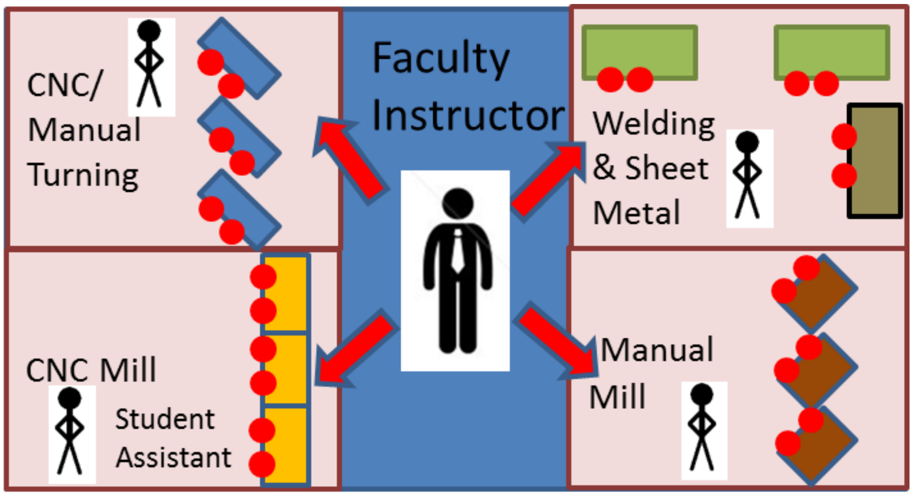

Figure 4. General laboratory layout. Stick figures represent student lab assistants; the round dots represent an enrolled student.

A few more distinctions may be required to fully understand the Figure 4 schematic. The lathes are designated as "CNC/Manual" because they were purchased with the intent of being operable in either a manual turning or CNC turning mode. This flexibility allows for two different types of turning labs without needing additional space—this flexibility is not a feature of the current milling equipment, with manual mills and CNC mills being multiples of two different machines. The area "Welding & Sheet Metal" has welding and sheet metal operations (shearing and punching) as the same station or location This area is used for creating the jaw cap components, where the steel strap is first sheared, punched and countersunk, then welded and grinded for the final products.

The faculty instructor is present and available to any of stations and must be knowledgeable in all areas. Most universities have available machinists or technicians to supervise the laboratory. However, NAU is fairly unique in that there is no such full-time technician in the Mechanical Engineering department to support any of the laboratories. This deficit is remedied in the manufacturing laboratory by employing up to four, part-time student employees to run a specific laboratory process. For practical reasons, only 2 to 3 student employees are available for hire at any section's time—the faculty instructor thus would primarily supervise the fourth position in any section, while still monitoring the other stations throughout the period. This problem is becoming mitigated as more experienced students become are available for hire from previous years' laboratory offerings.

Semester Schedule

The laboratory schedule, shown in Table 1, is organized into 14 week blocks—15 weeks are not scheduled as there is too much reshuffling of enrollment in the first week to accomplish any effective organization. A safety orientation is required in the first week of the laboratory offering—after the safety week, all students are placed in their 2-person teams; they begin acclimation to their partners by conducting some basic measurements operations with the measurement tools they will use during the semester. The 4-station rotation is prominent in the 8-week block of the schedule, starting from the third week of lab sessions. These labs have 2-week sessions at each station before rotating to a new station. The next 4 weeks, paired and sequential labs are accomplished in 2-week blocks (10 & 11 and 12 & 13), with up to 6 teams (12 students) each starting either lab 10 or 12. They conduct the subsequent lab together before swapping to the other pair of labs at the other stations for the remaining two weeks. The final lab 14 is conducted in a classroom, where the students assemble their product and calculate the processing time to create the product, based upon their actual documentation created during the semester. A final cost is estimated, based upon the processing time X hourly rate, plus material costs.

Table 1. Laboratory Descriptions. These description lab numbers are mapped directly into the semester schedule .

Lab number	Description	Comments
N/A	Safety Instruction	
1	Intro, basic measurements and safety	Orientation, basic measurements
2	Manual turn 1	Create the two guide pins
3	Manual turn 2	Create the single main screw handle
4	Manual Mill 1	Squaring and facing the two Jaw parts
5	Manual Mill 2	Drilling holes for the two Jaw parts
6	CNC Mill 1	Running the Tormach CNC mills on Jaw parts
7	CNC Mill 2	Running the Tormach CNC mills on Jaw parts
8	Welding 1	Gas metal arc welding (MIG)
9	Welding 2	Shielded metal arc welding (Stick arc)
10	CNC Programming	Simple CNC Programming for 3-axis mill
11	CNC Milling	Milling the CNC program of lab 10
12	CNC Turn	Creating the Main Screw via CNC turning
13	Hand Operations	Misc operations on parts
14	Assembly	Check fit of assembly; calculate total process time

Results and Conclusion

A paper survey instrument was combined with a graded assignment at the end of the semester. 52 students were enrolled in the Fall 2014 Laboratory; 50 students returned the survey. Most of the survey contained questions specific to certain laboratories noted in Table 1. Four issues are associated with learning and curriculum development.

Was the student aware of how to modify a part design and/or operation to enable a flexible process (i.e., simultaneous fabrication processes on the same end component at different locations)?

This question was to determine if the student understood the need for flexible manufacturing operations through the experience of operations on components occurring simultaneously (i.e., without a required order) for several labs. This topic was covered in the lecture, but not heavily addressed in the laboratory materials. 44% of the respondents were sufficiently clear in their responses that they indeed understood not only the need for flexible manufacturing (economics of using the equipment, scheduling as much product through the system as possible). The respondents also described how to redesign the operations (setups and procedures) of one particular component to enable such operations to be accomplished in any order.

Should the Manufacturing Processes lecture session be required for Mechanical Engineering majors?

This question must be addressed before the laboratory question following is addressed. The Manufacturing Processes Lecture (3 credit hours) is currently not a required course for the NAU Mechanical Engineering department, neither is the Manufacturing Processes Laboratory (1 credit hour, 3 hours contact time). Students are allowed to take the laboratory only if they sign up for the lecture. 44 % of the respondents replied that the lecture should be required for all Mechanical Engineering students.

Should the Manufacturing Processes Laboratory be required for Mechanical Engineering majors?

68% of the respondents replied that the laboratory should be required. This response is taken in light of the fact that the students realize the lecture would also be required for laboratory-enrolled students.

Should the CNC programming and wax cutting be deleted from the lab schedule, to enable two weeks for make-up labs as needed?

There is one set of labs that are conducted which still are process-oriented and not contributing directly to the production of the bench vise. These two weeks have the students learn very basic CNC (“G-Code”) mill programming, then cut a simple figure in wax on the CNC mills. Students were asked if they felt those two weeks were necessary in the overall lab offering. Those two lab deletions are of particular importance, as every week of the semester after the first week is scheduled for a new lab, with very little chance for ‘making up’ a lab when a student misses, even for medical reasons (including the week of Thanksgiving).

92% of the respondents stated that the CNC programming labs must be left in the laboratory. Those who wrote explanations had similar reasons: they enjoyed being able to create the code necessary to create a fabricated product. It is noted here that the product-oriented CNC labs were canned codes, created by the instructor and given to the students.

Anecdotal Observations and Future Planning

The author plans to offer the vise as the laboratory focus in the next academic year (Fall 2015). As the laboratory becomes more elaborate, a philosophy of ‘change one thing and evaluate’ is taking hold. The major change for the next offering will be to incorporate the CNC programming into a lab where the student-programmed, CNC-milled feature will be milled onto the back of the long jaw. This feature may be the university name, a logo, or simply the student’s initials. Thus, the CNC programming aspect of the lab will also be incorporated into the product fabrication process.

A question was verbally asked of all students at the start of each section’s first week by the instructor: “Have any of you ever had a manufacturing laboratory in college or even a shop class in high school?” Two of the three sections had only 3 students raise their hands (out of 40 students enrolled). The third section had roughly half of the 12 students raise their hands. Four of those students who replied positively in that section were exchange students from Brazil, where hands-on labs were required in both high school and their undergraduate courses in Brazil. The author notes that the NAU Mechanical Engineering Department has an excellent required laboratory that involves instrumentation of thermo-fluids experiments and statistical measurements. The manufacturing laboratory now allows students to also acquire hands-on experience in the creation of products and manufacturing process organization.

One secondary objective which is currently unmet is to have sophomore-level students enrolled in this laboratory, for the intent of these students to apply their hands-on knowledge to coursework in their Junior and Senior design classes. This objective is not satisfied primarily due to the manufacturing lab being tied to the Introduction to Manufacturing Processes lecture section. That section requires both strength of materials (sophomore level) and Materials Science (junior level) as prerequisites. These requirements are not unusual for a manufacturing course or lab; for example, the University of Tennessee-Martin has had essentially those same requirements for years, and other universities are undoubtedly similar.[6] These requirements are understandable in an engineering program, as a student should understand the basic engineering principles behind the manufacturing process under observation. These curriculum needs must be balanced by the advantages achieved when juniors and seniors can approach project-oriented design classes with basic manufacturing knowledge already in hand. However, it is unfortunate that the imposition of several prerequisites result in excluding essentially all sophomore and most junior students from the lecture, and thus the laboratory.
As noted earlier, equipment acquisitions have allowed more students to be enrolled in the course; Figure 4 illustrates that duplicate machines allow for multiple students to have hands-on education for the same operation in the same location. Over the past decade, the author was successful in securing 2 additional manual mills, 5 CNC mills, 3 CNC/manual lathes, an “Ironworker” (i.e., hydraulic sheet metal shear/punch/brake system) and other support tooling such as taps, machine tools, vises, etc. The new equipment, with more robust capabilities than older and worn-out machines, also enables the author to consider more interesting projects than the bench vise that could be also tied into other analytical courses. In particular, an air or Stirling engine could be created in the lab with today’s equipment, as implemented by other universities.[1] Such a product could positively benefit other courses. The functionality of the engine could be tied into the existing heat transfer course, for example, allowing for the students to experience how their theoretical education translates into an actual product realization.

Acknowledgements

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Best Practices for California Fundamentals of Engineering and Professional Engineering License Exams for Immigrant Engineers

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Abstract

This paper addresses some critical issues and challenges faced by immigrant engineers when they take the Fundamentals of Engineering (FE) license exam or the Professional Engineering (PE) license exam in California and across the United States. Each year, thousands of engineers come to the United States from different parts of the world. A large number of these engineers choose California as their permanent home. After arrival, most of these engineers realize that they need additional preparation to meet the professional standards set by the state government and other agencies. In the case of immigrant engineers, there is a tremendous amount of hard work and effort required by them to prepare for the FE exam, followed by the PE license exam. One of the authors of this paper recently emigrated from the Middle East and went through this challenging process himself to get his California PE license. He has developed a training program based on his personal experience with the intention of helping others to obtain their engineering licenses as well. More than 50% of the immigrant engineers who attended one of these training programs successfully completed their exams and received their Engineer-in-Training certification, which is a pass rate higher than the national average. This paper describes the curriculum, and best practices, and strategies adopted for this program. While this program was specifically designed for recent immigrants in California, lessons learned can be applied to other students interested in preparing for the FE or PE exams as part of the engineering licensing process.

Introduction

New immigrants are strongly represented in US engineering occupations, making up about one-quarter of the engineering workforce[1]. However, new immigrants often face special challenges in taking licensing exams, let alone passing them in a timely manner. Those who want to help the immigrant engineers need to understand the background of this group—their strengths and weaknesses—so that strategies to help them are designed appropriately.

There are basically two types of immigrant engineers, those who hold H-1B visas and those who are refugees or are seeking asylum in the United States (asylees). According to the Department of Homeland Security:

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> "The H-1B nonimmigrant classification is a vehicle through which a qualified alien may seek admission to the United States on a temporary basis to work in his or her field of expertise. An H1B petition can be filed for an alien to perform services in a specialty occupation, services relating to a Department of Defense (DOD) cooperative research and development project or coproduction project, or services of distinguished merit and ability in the field of fashion modeling… In order to perform services in a specialty occupation, an alien must meet one of the following criteria: (1) hold a U.S. bachelor's or higher degree as required by the specialty occupation from an accredited college or university; (2) possess a foreign degree determined to be equivalent to a U.S. bachelor's or higher degree as required by the specialty occupation from an accredited college or university; (3) have any required license or other official permission to practice the occupation (for example, architect, surveyor, physical therapist) in the state in which employment is sought; or (4) have education, specialized training, or progressively responsible experience (or a combination thereof) that is equivalent to completion of a U.S. bachelor's degree or higher in the specialty occupation, and have recognition of expertise through progressively responsible positions directly related to the specialty occupation. Specialty occupations may include, but are not limited to, computer systems analysts and programmers, physicians, professors, engineers, and accountants."[2]

The H-1B visa is intended for *temporary* workers. Tens of thousands of engineers holding H-1B visas have entered the US labor market over the past decade, including graduates of US schools and foreign-trained engineers coming directly from abroad. Immigrants now make up about one-third of computer hardware and software engineers and one–quarter of electrical engineers[3]. Some argue that the influx of these H-1B immigrant engineers has resulted in depressed job opportunities, lowered wages, and declining working conditions for U.S. engineering personnel[4]. Others argue that increasing the number of H-1B visas will stimulate the economy.

Refugee or asylees in the United States are also allowed to work in the USA.[5†] Those who are engineers by training can obtain a professional license, work in their field of study and training, and in most cases they will eventually become citizens of the United States. For the purpose of this paper we will refer to both refugees and asylees as "refugees" even if their immigration status may technically be different.

Tens of thousands of refugees resettle in the United States every year. In FY 2008 alone, 60,279 refugees were resettled by ten national voluntary agencies. All make lives for themselves in cities, towns, and suburbs across the country and all strive for the same thing—the opportunity for a better life. Many of these newcomers bring a few reminders of home, their families if they are lucky, and their past experience. This experience is vast and varied[6]. Refugee engineers are

† There are restrictions as to when asylum seekers are allowed to apply for permission to work (employment authorization) in the United States. Asylum seekers who are granted asylum may work immediately.

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classified in the highly skilled group along with doctors, lawyers, scientists, and other professionals.

In this paper we are going to focus on the second group---refugee engineers with foreign engineering degrees, with or without foreign work experience. These refugee engineers need to be retrained and prepared in order to be ready to launch into the employment market and make a positive contribution, with all the experience and advantages that they already have to offer.

Characteristics of Refugee Engineer

First, refugee engineers represent a variety of ages and generations. Almost 63% of the refugee engineers came to the US when they were between the ages of 21 and 34, 24% came when they were between 35-50, and 12% came when they were older than 50[7]. This makes them different on the level of experience, because the older they are, the more experience they have in their field. While these refugee engineers may have more practical work experience, they are coming to licensing exams that have been typically designed for recent graduates or engineers who may only be a couple years out of school.

Second, refugee engineers come from wide variety of engineering specializations with differences in their work experiences. Over the last decade, many new immigrants have come to the United States in the fields of software, IT, and computer engineering because of high demands in these areas. Many of the refugee engineers who came to Southern California during the last five years when faced the bad economy decided to change their engineering field in order to find work. Engineers who resettled in the United States had years of experience that varied from entry level technician to advanced managerial work, and encompassed activities that ranged from design to manufacturing to field work.

Next, refugee engineers have a spectrum of educational degrees: Bachelor’s, Master’s, or Doctorate degrees in engineering from different schools with different standards and academic levels. Even though the physics and mathematical aspects of all programs are almost the same, it is difficult for employers or licensing bodies to evaluate the quality of the education programs. The strong emphasis by licensing bodies for degrees from ABET-accredited programs and institutions can put these refugee engineers at a disadvantage compared to graduates from American engineering programs.

Finally, the following challenges are also common among refugee engineers:

- Language: Nearly all of the refugee engineers speak English but do not have English as a first language. Some are not fluent in English. Besides the difficulty in communicating engineering concepts using English terminology, this problem with language limits their

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marketing of themselves, especially as it relates to the engineering terminology and understanding the work requirements, laws, and ethics.
- Culture: Differences in culture leads many times to the lack of trust, misunderstanding, and hesitation by both refugee engineers and employers alike.
- Networking: In the United States, as in other countries, networking plays a big role in creating e opportunities and reinforcing the efforts to find employment.
- Background evaluation: In the United States, many employers would like to have candidates with US academic degrees and US experience, and they often ask for diplomas and references to support that. It is hard to convince many employers to give an engineer with overseas degrees and experience a chance.[8]

These characteristics and challenges add difficulties in building a comprehensive program to help all immigrant engineers who are looking for employment opportunities in the US, since it is difficult for the refugee engineer to compete with the local engineers especially during years with a poor economy or higher than usual unemployment. Still, refugee engineers bring with them many positive attributes which the engineers need to be reminded of, as well as need to be presented to potential employers:

- Motive: Many of the refugee engineers come with a lot of dreams and hopes. They are optimistic and positive, believing that they can prove that they deserve the opportunities before them. They are ready to accept the challenges of the hard work and low wages required to start with a new beginning.
- Education: The refugee engineer already has a degree or degrees with no loans or other financial obligations.
- Experience: Many of the refugee engineers come with work experience which can be a distinct advantage if it is presented in a professional way to highlight their skills and abilities, in addition to their educational credentials.
- Willingness to relocate: Refugee engineers often have no particular connection to a geographic area or to family ties, and as such are able to relocate to another area where they are more likely to get jobs.

Guiding the refugee engineers with a view of all the available options can help them refine their choices and correct the blurry picture of "how to start." The main goal is to have the refugee engineers take the best path based on both their abilities and what they are looking for. Our goal is to prepare them and avoid excessive delays which can add more complexities to their efforts in finding the right job and their healthy integration into the new community as an active and productive member[4].

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ROAD MAP TO EMPLOYMENT OPPORTUNITIES FOR REFUGEE ENGINEERS

Planning a path to opportunities for a refugee engineer has to take into consideration the job market standards and requirements and prepare the refugee engineer to meet those and to be a good candidate as soon as possible.

Studying and understanding the general and professional barriers to employment, and emphasizing the existing advantages that a refugee may have, will give a him or her a solid base with which to explore the right options and solutions. Many academic and training schools throughout the United States provide technical and theoretical programs which offer degrees and certificates, and most follow the workforce market needs. These can be good environments to supplement the refugee engineer's education or to help retrain them in different disciplines if necessary.

Engineering education in the US has traditionally involved the classical engineering disciplines civil, electrical, and mechanical, as well as some special disciplines such as chemical, industrial, petroleum, among others. However, with the changing needs of our technical society, the workforce now needs a wide variety of engineers with specialty skills. Even in the area of electrical engineering specialties are as diverse as information technology (IT), computers, networks, data systems, security, communications, and even mechatronics and nuclear engineering which may cross over several engineering disciplines. Also, we now have dozens of subdisciplines connecting engineering with wide variety of traditionally non-engineering industries and activities, such as medicine, physics, and astronomy.

Progress in industry and technology in the last decade has changed a lot of the concepts and thoughts in engineering in both theory and application, and that is now reflected in all the curricula used by engineering schools and training centers. Most refugee engineers came from countries with different (generally more basic) technical needs than the United States. Most refugee engineers need to change their approaches, standards, and perceptions as a first step, and they need to understand where they are on the new engineering map of employment opportunities. The road map has to have educational classes and workshops designed by academics and industrial professionals who can draw a broad picture with all the employment needs and possibilities to help the refugee engineers achieve their goals. The following are suggested steps for refugee engineers to obtain the proper tools, resources, and references to compete for employment opportunities:

- Evaluate on the level of language abilities to see if they can handle technical communications within an acceptable level;
- Attend workshops to get the information about the engineering market, so that they will know about the new environment they intend to merge into;

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- Decide according to their background, life goals, and abilities what path they need to take. This could involve changing disciples, studying for another degree (such as pursuing a Master's or Doctorate degree in their field), testing for a license, or training for a certificate;
- Become trained to get the skills to market themselves, network, and know about the geographical distribution of the industries so that they can decide if they need to move to find the best employment opportunity. For this last step, people from the staffing agencies, human resource personnel, and recruiters may be able to help.

Figure 1 summarizes the roadmap proposed to assist refugee engineers to plan their path to gainful employment opportunities. In this paper, we will focus on one of the options available to help the refugee engineers obtain a nationally recognized level of competency which will allow them to competitively seek employment in the area of their training and skills, namely obtaining an FE or PE license.

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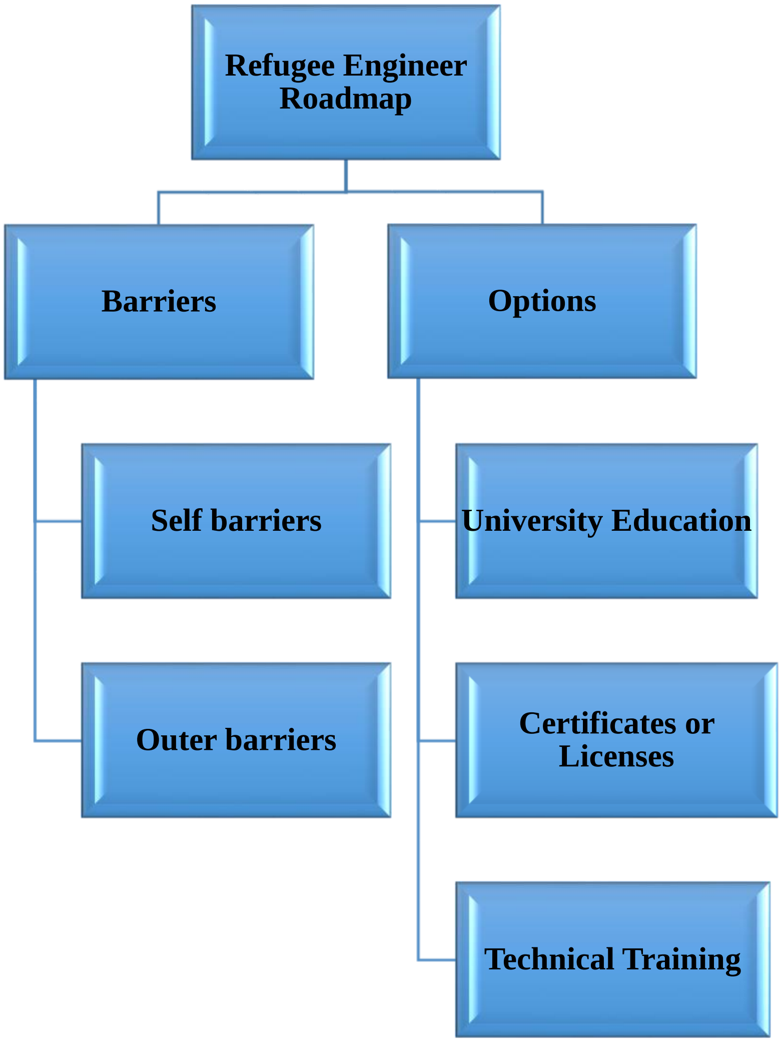

PROFESSIONAL LICENSES FOR REFUGEE ENGINEERS

The United States does not have a national engineering license. Licenses are issued by state boards of licensure or registration. And while some engineering professions do not require licensure (they may be exempt due to "industrial exemptions" or they may not provide services to the public), in many disciplines such as Civil Engineering, a Professional Engineer (PE) license is mandatory for career advancement.[9]

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The Fundamentals of Engineering (FE) exam, also referred to as the Engineer-in-Training (EIT) exam, is the first of two examinations that engineers must pass in order to become licensed as Professional Engineers in the United States. The FE exam is designed and administered through the National Council of Examiners for Engineering and Surveying (NCEES), which is a national non-profit organization, composed of engineering and land surveying licensing boards representing all U.S. states and territories. NCEES previously held the FE exam twice a year on the same two days all over the United States---once in April and once in October. However, starting in 2014, the FE exam changed to Computer-Based Testing (CBT) whereby the exam can be scheduled on any working day during eight months each year. The FE exam is now a six-hour computer-based exam consisting of 110 multiple choice problems which is offered at NCEES-approved Pearson VUE test centers. The FE exam is offered in seven disciplines shown in the list below:

1. FE Chemical
2. FE Civil
3. FE Electrical and Computer
4. FE Environmental
5. FE Industrial
6. FE Mechanical
7. FE Other Disciplines

The FE exam is open to anyone with a degree in engineering or a related field, or is currently enrolled in the last year of an ABET-accredited engineering-degree program. Some state licensure boards permit students to take it prior to their final year of school, and numerous states allow those who have never attended an approved program to take the exam if they have a state-determined number of years of work experience in engineering. Some states allow those graduates with ABET-accredited "Engineering Technology" or "TAC" degrees to take the examination. The states of Michigan and California have no admission pre-requisites for the FE exam, however California will not issue an “Engineer-in-Training” (EIT) certificate until the applicant has obtained the requisite number of years of experience and/or education in addition to passing the exam.[10]

Certification as an “Engineer-in-Training” which is a professional, recognized, and appreciated certification provides the following benefits to refugee engineers:

- Opens the door for them to apply to many jobs, and presents a good addition to their resumes in order to compete in the work market;
- Helps them to learn terminologies, ethics, and standards in the US workplace;
- Supports them by refreshing their knowledge of the mathematics, formulas, and facts with examples reflecting engineering industries and industry standards in the US;

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- Reinforces their confidence when they have taken and passed the same exam as other engineers across the United States;
- Opens the way for refugee engineers with enough experience to sit for the PE license exam;
- Provides the shortest way to become licensed as an engineer in the United States.

"Professional Engineer" (PE) means an individual who has fulfilled education and experience requirements and passed rigorous exams that, under State licensure laws, permits them to offer engineering services directly to the public. Engineering licensure laws vary from state to state, but, in general, to become a PE an individual must be a graduate of an engineering program accredited by ABET, pass the Fundamentals of Engineering (FE) exam, gain four years of experience working under a PE, and pass the Principles of Practice of Engineering exam.[11] The PE exam is also designed and administered by NCEES. California requires a total of six years of education and experience (assuming graduation from an ABET-accredited program) in addition to passing the FE exam in order to sit for the PE examination.

A training program was developed to provide to the refugee engineers assistance in preparing for the FE exam. As a way to cover the greatest needs of the widest group of engineers, we recommended that the students apply for the "FE Exam – Other discipline" which is the more general engineering exam. Such a step planned for a fast review course which targeted more than just the engineering course material itself by addressing the following:

- Collecting the engineers in a single group which was composed of different ages, generations, fields, and levels and types of experience.
- Considering refugees' academic background as the basis to develop a course syllabus, and using teaching approaches which can always be modified to meet exam requirements and student needs.
- Using the course as an opportunity to teach the standards, terminology, and applications of engineering in the United States.
- Bringing the refugee engineers together in a group to face challenges that will help lead to interactions between them and by encouraging each other, studying together, and sharing thoughts and experiences create good networking in the future.

OUTCOMES OF REFUGEE ENGINEERING TRAINING PROGRAMS

In January 2012, a course was arranged through the Welcome Back Center – a Grossmont Community College Auxiliary in San Diego, California. Eighteen Iraqi refugee engineers enrolled in the course to prepare for the April 2012 FE exam. The course was taught by a Professional Engineer who was a city employee with successful private FE teaching experience

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and who had the same background as the students. An author of this paper assisted in teaching this course, not just to help the students in reviewing FE exam materials, but also to help in guiding them to go further in making clearer career choices. In addition to the exam preparation, we provided activities through the course like inviting speakers from staffing agencies, National University, and Qualcomm human resources. Through several workshops they helped the group to make future career decisions. The classes were held on Saturdays and Sundays, eight hours each day, to train the engineers to face the same pressure of the exam. The course used Cuyamaca Community College facilities and continued for three months.

In this first cohort of students, 8 engineers passed the exam and became certified as EIT engineers out of the 16 who took the exam; 4 passed the next FE exam on the second try; 4 became employed as engineers within 6 months of the course; 3 applied for engineering master's degree programs; 1 became licensed as an HVAC engineer and started his own project; 1 (an author in this paper) passed the Professional Engineering exam in electrical engineering, instructed the next four FE exam preparation courses, and became employed as associate faculty at National University; 4 became employed in technical jobs; and 2 got internships with the city through the program, one of whom was picked as 2012's Best Volunteer and was subsequently hired as an engineer in 2013. Each engineer who took the course received a certificate acknowledging that they had completed the FE exam review course, and also received a signed award from their state senator. The pride of the engineers and their families at the ceremony celebrating the completion of the course was palpable. For many this was the first tangible step toward regaining their status as an engineer in their new home country.

In August 2012, an author of this paper put together a course outline and goals along with a textbook and course requirements. In this second cohort, 22 refugee engineers enrolled in the course to prepare for the October FE exam: 17 Iraqi engineers, 1 from the Philippines, 1 from Ukraine, 2 from Iran, and 1 from Albania. The revised curriculum added exam techniques, and additional activities and workshops were improved to include visits to the National University, visits by Aerotech staff, agency counselors (i.e. professors), and a member of the California Board for Professional Engineers, Land Surveyors, and Geologists. The hours and time were kept the same as in the first cohort. The classes held at the Cuaymaca Community College facility.

In this second cohort, 7 engineers passed the exam and became certified as EIT engineers out the 17 who took the exam; 3 passed the next FE exam on the second try; 3 became employed as engineers within the next 6 months; 4 applied for engineering master's degree programs; 4 applied to different licensing programs (QC, PMP, and contractor); 5 became employed in technical jobs; and 2 got internships at the city and the county through the program.

The April and October 2013 FE exams were preceded by training courses in January and August of 2013. In the third and fourth cohorts, 16 Iraqi refugee engineers enrolled on the first one and

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15 Iraqi refugee engineers enrolled in the second. Course outlines were modified to meet students' needs, and workshops and activities supported by volunteer speakers and counselors continued to help individuals and groups with career decisions. Grossmont Community College facility hosted the course on Saturdays and Sundays.

The results of the training of the third and fourth cohorts of students are as follows: 11 engineers passed the exam and became certified as EIT engineers out of the 25 who took the exam; 5 became employed as engineers within the next 6 months; 5 applied for engineering master's degree programs; 2 passed the PE exam in mechanical engineering in 2014, one became employed by General Electric in Texas, and the other employed by the City of New York; 3 passed the next FE exam on the second try; 7 became employed in technical jobs; and 2 got internships at the City of San Diego through the program and one was hired at the end of 2014.

In 2014 the FE exam changed to Computer Based Testing (CBT). The course outline was rewritten to meet the new exam techniques. Refugee engineers were encouraged to use their laptops to train in solving examples. The course was held February through August 2014 at El Cajon County Library as the Grossmont/Cuyamaca Community College facilities were no longer available. The course was extended to 6 months, one class each week---Sundays for six hours. Additional career exploratory activities continued to be part of the course.

The results of the training of the fifth cohort of students in 2014 are as follows: 15 Iraqi refugee engineers enrolled in the course; 5 refugee engineers passed the exam and became certified as EIT engineers out of the 9 who took the exam; 5 who were "self-studying" planned to take the exam in the near future; 4 became employed as engineers during and after the course; 5 applied for engineering master's degree programs; 1 applied for and passed the contractor license exam; and 2 became employed in technical jobs.

After five FE review courses, the outcomes are summarized in Table 1:

Course Year (# of class)	Enrolled in the FE courses	Took the exam	Passed the exam the 1st time	Passed the exam on the 2nd try	Employed in engineering positions	Passed the PE license exam	Enrolled in Master's degree programs	Licensed with other licenses than the EIT or PE	Employed in technician positions
2012 (#1)	**18**	**16**	**8**	**4**	**7**	**1**	**3**	**1**	**4**
2012 (#2)	**22**	**17**	**7**	**3**	**3**	**-**	**4**	**4**	**5**
2013 (#1)	**16**	**14**	**6**	**3**	**4**	**2**	**3**	**-**	**3**

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2013 (#2)	**15**	**11**	**5**	-	**2**	-	**2**	-	**2**
2014	**15**	**9**	**5**	-	**4**	-	**5**	**1**	**2**
Total	**86**	**67**	**31**	**10**	**20**	**3**	**17**	**6**	**16**

Looking at the data on the outcomes of these five cohorts shows the success of the training program for refugee engineers. The total number of the refugee engineers who took the FE exam was 67 and the number who passed on either the first or second attempt and became certified as Engineers-in-Training was 41. Additionally, 20 out 86 were employed in engineering positions (23.3%) which if added to those who were employed in technical positions which is 16 out of 86 (18.6%) results in a total of 36 out of 86 (41.9%) who successfully changed from being unemployed or had non-engineering jobs to engineering or technician jobs. Furthermore, 17 out of 86 (19.8%) mostly the fresh graduate engineers realized after the course that they are able and need to pursue an advanced degree. They started investigating the right program for them. Some took the GRE exam with a result that enabled them to qualify to enroll in a full time master's degree program. Others, especially those who already had jobs, choose to enroll in on-line and part-time programs. Some participants, 6 out of 86 (6.9%), saw an opportunity to start in another direction, decided to change careers, and pursued other licenses.

In the last two years, 3 out of 86 (3.5%) went on to pursue their PE license within the narrow limits of this study. This can be a big step for a refugee engineer who lacks US work experience and has limited familiarity with the regional standards. Passing the PE exam required a considerable effort of preparation and study.

The table below compares the passing rate of refugee engineers who took this training program compared to the passing rate of all engineers in California. In the first four cohorts of students, the passing ratio was above 50%, with a range of 50-72%. This compares very well with the range of California EIT passing rates of 51-61% in these four exams.

Exam time	FE course passing ratio*	California EIT passing rate[12]	Difference
April 2012	50%	61%	-11%
October 2012	64.7%	51%	+13.7%
April 2013	64.3%	61%	+3.3%
October 2013	72.2%	54%	+18.2%

*includes examinees passing on both first and second attempt

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CONCLUSION

In summary, refugee engineers are well-motivated for professional jobs; what they need is the right guidance and support from the academic and professional community. Effective programs can help a successful refugee engineer positively influence his family and his community, and enable him to contribute to the engineering industry in the United States. Programs and roadmaps such as those outlined in this paper can ultimately save a lot of tax monies spent on welfare for low income and unemployed refugees each year. Guidance services can be developed into a general program that any immigrant engineer can be referred to, as soon as he or she has the proper legal status. This will avoid confusion and allow an easier transition for both the engineer and the engineer's family.

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Training in Technical Writing for Engineering Graduate Students

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Abstract

Most types of writing that engineering students need to master in order to communicate their research efforts can be classified as technical writing. Four years ago, UNLV's Howard R. Hughes College of Engineering began to offer their graduate students a free technical writing workshop series to improve students' success rate in acceptance of papers for conferences and journals and award of graduate fellowships. Co-taught by the college's Technical Writer and the university's Science, Technology, Engineering and Mathematics (STEM) Librarian, the workshops offered in the fall semester include training in reference management systems and basic information literacy. The spring semester workshops focus on how to prepare papers for submittal to conferences and journals and technical reports as part of the requirements for grant funding. The keystone workshop of this series, offered in the fall and spring semesters, is *Literature Review for Engineers: How to Search, How to Write*. During this workshop, the STEM Librarian describes a quality search process and demonstrates methods to organize and evaluate different forms of literature and the Technical Writer describes the writing of a literature review as consisting of three levels. The final workshop of the academic year is a *Technical Writing Intensive*, during which the students work on their papers and reports. They are encouraged to bring their dissertations or theses as well, and are provided with one-on-one counseling from the instructors. All workshops include active learning and lecture as instruction methods.

Introduction

Engineering graduate students typically complete a research project and write a thesis or dissertation that includes a literature review. At the University of Nevada, Las Vegas (UNLV), engineering graduate students also are encouraged to submit papers to conferences and journals as well as participate in writing technical reports required by federal or state grant-funding agencies. Students also may apply for graduate fellowships that require a description of the applicant's research project. The term 'technical writing' is used hereafter to describe the forms of writing that the students encounter as they attempt to describe and discuss their research.

Conducting a literature review requires a variety of skills, including information literacy, critical reading, and composition as well as time management. While faculty and program staff may assume that entering graduate students are equipped with these skills, many are not[1]. In fact, many graduate students experience significant barriers to initiating and completing quality literature reviews, including library and composition anxiety, with higher levels of anxiety correlated with lower scores on literature review assignments [2].

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Library anxiety is a complex set of emotions or an affective state that library users, including students, may experience when faced either with the prospect of using unfamiliar library resources and facilities or when interacting with library staff. Library anxiety may delay or even stop the student from attempting to use recommended but unfamiliar library resources[3] or cause them to delay or end their information search attempts out of frustration rather than a sense of completion[4]. Library anxiety as described by Onwuegbuzie[5] can include “interpersonal anxiety, perceived library competence, perceived comfort with the library” as well as “location anxiety” of materials in the library, “mechanical anxiety” related to equipment and tools, and “resource anxiety” regarding the delay in acquiring resources, which also can be described as interlibrary loan anxiety. While graduate students appear to have lower levels of library anxiety than do undergraduates[6], it does affect them. Moreover, international students and those for whom English is not their native language may experience increased levels of library anxiety[7].

Composition anxiety, otherwise known as writer’s block, is a set of emotions leading to avoidance behaviors and related to feelings of lack of competency in writing[8]. Composition anxiety as described by Onwuegbuzie[9] can include “content anxiety” regarding the student’s writing; “format and organizational anxiety” when using a style guide; “mechanical anxiety” when using a computer, software, or file storage; and “fear of negative evaluation”. This affective state may be experienced by both undergraduates and graduate students as well as professionals[10] .

Levels of composition anxiety can be increased by compulsory, high stakes assignments or writing courses[11]. This anxiety may increase further when compounded by the trepidation many graduate students experience when making the transition from student to independent scholar[12]. Compounding the apparently common composition anxiety among graduate students in general, there is a prevalent stereotype that engineers are poor communicators. A very pervasive cultural belief related to communication skills, particularly written communication, exists among engineers; this is reflected in a currently popular T-shirt, as shown in Figure 1.

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Figure 1. A popular T-shirt reflecting a belief among engineers that they do not have good communication skills[13] © Robin Lund.

In fact, high levels of composition anxiety as well as these prevalent attitudes about and among engineers may encourage engineering students to avoid efforts to improve their communication skills. This resigned attitude will hamper their success as students and professionals, particularly if they continue in academia, where grant writing and publishing are of paramount importance.

The negative emotions associated with higher levels of library and composition anxiety may lead to self-defeating strategies among students when conducting literature reviews[14] . Several interventions and instruction offerings have been found to reduce one or both forms of anxiety. As described earlier, those students who are experiencing difficulty with English as their non-dominant language – either because it is not their native language or with English as their first language but having developed poor language skills – may require instruction and interventions that pay particular attention to their cultures and affective states[15]. In addition, the format of instruction will affect students with different preferred learning styles in different ways. Of note, although many students express a dislike of group work, it is commonly thought to be among the most effective learning activities, as it necessitates active learning activities[16]. However, some international students may find active learning at odds with the style of instruction with which they are more familiar. Carefully structured small-group activities[17] and use of a variety of learning activities to appeal to a variety of learning style preferences[18] may provide the best approach to group instruction to reduce library and composition anxiety.

Integration of library and composition anxiety-reducing instruction into credit-bearing courses, such as research methods courses, may provide benefit to students[19]. Direct instruction by faculty who also may be some students' academic advisors, however, may impede student involvement in group discussions or questioning that may reveal ignorance or vulnerability on the part of the student[20]. Further, non-compulsory workshops provided by librarians and other experts may

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alleviate library and composition anxiety[21, 22]; however, the students must be motivated to make the time to attend these instructional sessions[23]. Also of value are workshops co-taught by two or more faculty or program staff who model the behaviors and describe first-hand experience with the habits of practice expected of academic professionals[24, 25]. Clearly, interventions such as non-credit-bearing workshops can lead to greater competence and confidence in the literature process[26], and can assist graduate students in their transition to become independent scholars[27].

Background

Four years ago, the Howard R. Hughes College of Engineering at the University of Nevada, Las Vegas (UNLV), began to offer the graduate students a free workshop series on technical writing to improve their success rate in acceptance of papers, reports, dissertations, theses, and graduate fellowships. The planning for these workshops was based on ideas from Dr. Mohamed Trabia, Associate Dean for Research, Graduate Studies, and Computing at the College of Engineering; he had been advocating for some time on the need to provide training in writing and communications skills to engineering students. These skills would be useful both while pursuing their degrees as well as in preparation for future jobs in industry or academia. All costs pertaining to the workshops were paid by the Dean's Office, and the Technical Writer of the college was responsible for planning the workshops each year.

In Academic Year 2011 – 2012, which was the first year these workshops were held, three presentations were given specific to technical writing. The first, held in October 2011, was a tutorial on RefWorks software given by the (former) Engineering Librarian. In February 2012, a three-hour presentation on technical writing for papers and proposals was given by the Technical Writer. In March 2012, those students who attended the February presentation were invited to attend the Technical Writing Intensive, during which they brought their own papers, reports, theses, and dissertations, among other projects. This three-hour training session was broken up into five segments, each with a 10-minute refresher on a key point, and then 20 minutes in which the students work on their own material and receive individual coaching.

Evolving Structure of the Technical Writing Workshop Series

Over time, the Technical Writing series evolved based on feedback from the engineering graduate students as well as their faculty advisors, as shown in Table 1. All the workshops take place on Friday mornings, in an effort to avoid conflict with required courses the graduate students may be taking. The workshops range in duration from one to three hours. Percentage of enrolled graduate students attending these workshops has ranged from 3% to 14%.

During the past two years, the series has begun in September with an hour-long introduction to all the resources that the engineering graduate students have at their disposal to help them with their writing projects. These resources include:

1. Thesis and dissertation information from the Graduate College, a website entitled *Resources for Proposals, Papers, and Reports*, provided by the College of Engineering;[28]
2. Information regarding UNLV's Writing Center, which provides online assistance as well as seminars and one-on-one counseling;[29]

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3. Online resources for Engineering and Computer Science from UNLV's University Libraries;[30] and
4. Resources of UNLV's Graduate College.[31]

In addition, this introductory workshop has gone over the resources provided by the Technical Writer of the College of Engineering and the Science, Technology, Engineering, and Mathematics (STEM) Librarian. Finally, the schedule of other technical writing workshops for that year has been presented.

After the *Introduction to Technical Writing* workshop in September, the next two workshops focus on training the students on RefWorks software, which is available for free through UNLV's Office of Information Technology. The STEM Librarian provides this training, both in the basics of RefWorks as well as advanced techniques, particularly how to use Write N Cite.

The last workshop of the fall semester, *Writing a Literature Review*, is three hours long, and addresses how to do a quality literature search and how to write a literature review. Details of this workshop are presented in the next section of this paper. Beginning with the literature review workshop, the students must demonstrate a commitment to their own professional development in order to attend. For this and each of the following workshops, students must register in advance, bring their own work and equipment, and prepare an assignment in advance of the workshop. In Spring 2015, a second session of this workshop was provided and was well-attended.

Table 1. Technical Writing Workshops at UNLV's College of Engineering

Workshop Title	**Date**	**Attended**	**Percentage of Enrollment**
2011 – 2012 Total College of Engineering (COE) Graduate Enrollment: 230			
RefWorks Tutorial for Engineers	October 2011	12	5
Technical Writing for Papers and Proposals	February 2012	25	11
Intensive on Technical Writing	March 2012	23	10
2012 – 2013 Total COE Graduate Enrollment: 214			
Engaging Best Practices to Successfully Publish a Journal Article: for Engineers	September 2012	22	10
RefWorks Tutorial for Engineers	September 2012	8	4
The Basics of Technical Writing: Session 1	February 2013	24	11
The Basics of Technical Writing: Session 2	March 2013	23	11
Intensive: Preparing a Paper for Publication	April 2013	11	5
2013 – 2014 Total COE Graduate Enrollment: 231			
Introduction to Technical Writing	September 2013	25	11
RefWorks I for Engineers: The Basics	September 2013	17	7
RefWorks II for Engineers: Advanced Techniques	October 2013	17	7
Writing a Literature Review for Engineers	November 2013	17	7
Technical Writing for Papers, Reports, and Proposals	February 2014	21	9
RefWorks for Engineers (I and II combined)	March 2014	6	3
Preparing a Grant Fellowship Application	April 2014	7	3
Intensive on Technical Writing for Engineers	May 2014	10	4

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Workshop Title	Date	Attended	Percentage of Enrollment
2014 – 2015 Total COE Graduate Enrollment: 229			
Introduction to Technical Writing	September 2014	18	8
RefWorks I for Engineers: The Basics	September 2014	15	7
RefWorks II for Engineers: Advanced Techniques	October 2014	9	4
How to Conduct and Write an Effective Literature Review	November 2014	17	7
How to Prepare a Paper for Publication	February 2015	29	13
How to Prepare a Technical Report	March 2015	20	9
How to Conduct and Write an Effective Literature Review	March 2015	32	14
Technical Writing Intensive	April 2015	TBD	TBD

In the Spring semester, the focus moves towards *How to Prepare a Paper for Publication* and *How to Prepare a Technical Report*, the latter being an important skill since most grants require interim and final reports to the funding agency. Finally, the *Technical Writing Intensive* is an invitation only workshop, offered only to students who have attended the Literature Review, Paper, or Report workshops. The attendance for this workshop generally is small; however, these are the students who have attended three or more workshops over the year and are engaged in improving their technical writing skills. The students who go through the Intensive – in which they work on their own papers, dissertations, theses, reports, or graduate fellowship applications – receive individual counseling from the instructors during the workshop.

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Literature Review Workshop

The keystone workshop of this series is *Literature Review: How to Search, How to Write*. Instruction methods include active learning as well as lecture. This is the first workshop in the series where pre-registration is required. After signing in and receiving handouts, the students may select their seats and set up their computer or tablet. The STEM Librarian and Technical Writer mingle informally with the students until the workshop begins.

The Ice Breaker

The three-hour workshop begins with an 'ice breaker' to address library anxiety and fear of writing by asking the students how they *really* feel about writing literature reviews. After some diffidence and caution, someone offers that they hate it. This triggers a whole slew of responses: "I would rather be doing math," "I am scared of writing," and so forth.

Once their concerns and fears about writing are acknowledged in the ice breaker, the next step is to generate an awareness of how important communication skills, especially writing skills, will affect the students' careers. A discussion ensues to share the experiences of the instructors and students in the publishing process in order to create this awareness. This dialogue touches on skills that result in a significant success rate in the acceptance of papers by journals and conferences, among other venues. At this point, the students realize why good writing skills are important to them. Now, they can focus on the next two segments: how to conduct a quality literature search and how to write a literature review.

How to Conduct a Quality Literature Search

Next, is an active learning segment, involving small groups of students discussing the tools and techniques they have used to complete a literature review; afterwards, they share key points with the whole group. The instructors also share their best and least successful practices and favorite tools during this discussion, including a discussion of techniques to avoid plagiarism. Next, the STEM Librarian provides a lecture describing a quality search process and demonstrating methods to discover, translate, organize, evaluate, store, and cite different forms of literature. This segment highlights tools and techniques not already described by the students during the earlier discussion. Student volunteers are brought to the front of the room to demonstrate tools, and in particular, how to navigate successfully an unfamiliar search interface and how to request materials through interlibrary loan. Handouts are provided with tool names, samples of tools interfaces, and contact information for the STEM Librarian and UNLV Libraries.

How to Write a Literature Review

After a break, the Technical Writer uses the next hour and a half to describe the steps in writing a literature review. This process is presented in three levels of mastery. Level 1, essentially a tabular bibliographic annotation, is expected of an undergraduate student; however, many workshop participants identify their writing at this level. The workshop provides the students the skills to ensure that if they are writing a Level 1 literature review, at least it is a good quality literature review at that level.

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Level 2 moves from annotated bibliography to finding patterns among the literature selected and to contrast and compare the authors' findings. According to Webster and Watson[32], this level moves from being author-centric, as with Level 1, to concept-centric. In other words, the student is asked to organize the material around key concepts. It is emphasized in the workshop that this is the level that graduate students are expected to achieve.

At this point, the workshop moves into an active learning segment, in which pairs of students work together to draft and then analyze each other's literature reviews. The period of time given to these students generally allows enough time for them to create a Level 1 literature review of perhaps one, maybe two works. It is intended that they might realize that it would be useful to form writing groups to continue the peer review process after the workshop ends. After the active learning segment, the workshop continues with a description of a Level 3 literature review, as incentive for continued learning.

The key feature of a Level 3 literature review is synthesis of the material[33]. It has a narrative quality and reflects a thorough understanding of the field, often gained only by experience. During the workshop, a Level 3 literature review is described; however, it is made clear to the graduate students that they are not expected to achieve this level, although they are welcome to try. This level of writing is expected of academic faculty, and many of the students who attend this workshop are in the process of obtaining their Ph.D. degrees with the intention of an academic career. In addition, at UNLV's College of Engineering, many of the graduate students are encouraged to co-author papers with faculty, who would prefer a Level 3 literature review be written.

Breaking the writing process into three levels is something that engineering students can understand and get excited about. Use of a table for the draft of a Level 1 literature review appears to decrease composition anxiety. Further, it gives them scaffolded, achievable goals for their professional development.

Assessment

The learning outcomes for the workshop series are:

1. Students will discover that their lack of familiarity with the library and/or particular library resources is not a reflection of their intelligence, and will be willing to attempt new tools.
2. Students will use tools and resources for research and writing that they discovered and demonstrated in the workshop.
3. Students will overcome anxiety about asking questions of the Librarian, and seek out assistance or advice as they complete their literature search tasks.
4. Students will realize and come to grips with some of their fears about writing in order to move past these fears.
5. Students will realize how important writing skills are for their success in college as well as in their career.

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6. Students will have a desire to continue developing their writing skills after the workshop series is complete and have developed a commitment to lifelong learning.

During the first two years of this workshop series, the attendees were surveyed as to the usefulness of these courses. Their comments helped modify and refine the workshops into what they are today. For example, earlier workshops had such feedback requesting that more time was spent on a couple of key topics and to provide more examples of the approaches being discussed. Later workshops accommodated this type of feedback. Another type of feedback was in the form of specific questions the graduate student had regarding referencing software, for example. In these cases, either the STEM Librarian or the Technical Writer contacted the student directly to provide additional guidance. The workshops continue to be modified and refined based on written and verbal feedback provided by the students as well as by their faculty advisors.

Other methods of refining the course material to keep the workshops relevant to the needs of the students included feedback provided by their faculty advisors. One example of this feedback includes requests by faculty to train students about plagiarism and ethics in publishing. In fact, the *Writing the Literature Review* workshop was developed as a direct response to an overwhelming request by faculty for this type of training for the engineering graduate students.

Conclusion

Anecdotal evidence for the series' success is strong. During the 2013-2014 academic year, most students who have completed the series won 'best thesis' and 'best dissertation' awards as well as received graduate fellowships and financial prizes. One graduate student, upon taking these workshops, had her technical report published[35]. Several attendees have requested reference consultations or other assistance from the STEM Librarian. Many faculty send graduate students who are co-authoring papers or preparing grant-related reports to the Technical Writer for assistance. Several faculty now require workshop attendance for their graduate students. Despite this strong anecdotal evidence, this workshop series would benefit from more formal assessment and an assessment plan is in development.

In 2014, the UNLV Libraries successfully nominated the workshops for inclusion in the Graduate College Research Certificate Program[34]. Inclusion in the certificate program will provide an external motivation for participation, as students who complete six of the approved campus workshops and then complete a presentation of their research at an annual campus symposium or professional conference will receive a program completion notation on their university transcript.

Changes in the workshop series continue in response to informal feedback. For spring 2015, an additional *Writing the Literature Review* workshop was offered because most graduate students and their faculty have indicated that this content is essential to their success. Additionally, the spring 2015 workshop series is open to registrants from all STEM academic units. In fall 2015, the RefWorks workshops will be expanded in content to discuss several available reference management tools. Given the quickly changing capabilities of many referencing software tools,

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including some that are open access, future workshops will be entitled *How to Use Referencing Software for Research,* and will cover several different tools.

While these workshops are designed to be non-compulsory, the College of Engineering seeks to increase attendance. In the 2014-2015 academic year, UNLV's College of Engineering had 229 graduate students, and the highest percentage of enrolled engineering graduate student attendance was 14%. Some of these students had attended the workshop series the previous year, and some students will repeat the same workshop to gain additional knowledge and assistance. Future study is underway to investigate how to improve attendance and implement more formal assessment of student learning in each workshop.

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Introduction to Technical Problem Solving using MATLAB and LEGO MINDSTORMS NXT

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Abstract

The modern day engineering student is eager to combine theoretical principles with practical aspects. This paper gives an overview of a junior level course titled "Introduction to Technical Problem Solving," that combines computer programming with engineering design. The use of MATLAB and the LEGO Mindstorms NXT in the entire course is what distinguishes it from similar courses taught by other instructors of the course.

The motivation for adopting this new approach stems from (i) the availability of the free source RWTH- Mindstorms NXT Toolbox[1]for MATLAB that allows for interactive communication and debugging via Bluetooth and USB, (ii) the ability to immediately observe the practical results of coding, (iii) the flexibility in design that LEGOs provide, (iv) the ability to use only Matlab for the entire course, and (v) the ability to better prepare students for life-long learning due to the reinforcement of theory via a hands-on approach.

Students spend the first two weeks working individually and then in teams of two or three members. A Matlab concept is introduced by writing a short program and viewing the theoretical results, followed by programming the LEGO Mindstorms NXT (NXT) to illustrate the concept. Projects are assigned throughout the semester. The final project is open-ended, allowing students to demonstrate their mastery of the concepts based on their level of competency. This approach highly motivates the students as they try to outperform their peers, often resulting in outstanding designs. Each team is evaluated by the rest of the class which allows the instructor to include student feedback in the final assessment. Furthermore the instructor serves as a mentor throughout the semester. In some situations a misunderstanding in programming logic may not be obvious to the student until the code is executed via the NXT. Occasionally a situation arises that demands that both the instructor and the group of students work as a team to resolve the problem. This allows the instructor to be included in the student's plan and refrain from interjecting a sophisticated solution that may be above the student's level of comprehension. These situations benefit both the student and the instructor and can only be obtained from experience.

Introduction

Since the Fall 2009 semester, the approach used in teaching the course *Introduction to Technical Problem Solving (ME 105)* has been based on the model discussed in the paper Computer Applications in Mechanical Engineering[2]. The mode of delivery is two 50-minute lectures and

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one 2-hour 45 minute laboratory per week. The prerequisite courses are Statics and Electrical Circuits. The class size is 30 students per section with an average of five sections per year. Typical enrollment consists of students who have transferred from various community colleges and others who have completed their sophomore coursework at our institution. For most of the students, ME 105 is the first programming course encountered. The design component of the course was implemented by using the Parallax Basic Stamp microprocessor[3] to program a Parallax robot (Boe-Bot.) The microprocessor is programmed using PBasic which is a variant of the basic language. There were two main concerns regarding the Boe-Bot project. First, some students, who had not taken a circuits course with a laboratory component, were at a disadvantage when trying to create the circuitry needed for their project. Second, while two-thirds of the semester was dedicated to Matlab programming, the Basic Stamp microprocessor cannot be programmed with Matlab. A search was conducted for a robotics kit that would address both concerns. The RWTH- Mindstorms NXT Toolbox[1]for MATLAB was selected and in Fall 2014, students in one section of the ME 105 course were introduced to the toolbox.

Course Structure

The syllabus covers all items listed in the learning outcomes which state that the student should be able to:

1. Use scalar and matrix operations and linear algebra techniques to solve engineering problems.
2. Generate a Graphical User Interface (GUI) to effectively present solutions in an interactive MATLAB environment.
3. Solve systems of linear ordinary equations using Gauss' method and, for the special case of a 3x3 system, generate solutions via a graphical method.
4. Read and write MATLAB data files and import data into MATLAB from an Excel spreadsheet.
5. Write programs that involve user-defined functions, loops, and conditional statements.
6. Solve initial value problems using the Runge-Kutta 4^{th} -5^{th} Order Method in the MATLAB domain and via SIMULINK.
7. Extend their programming skills by participating in a final team project that requires the use of a microcontroller. Matlab will be used to program the LEGO Mindstorms NXT.
8. Demonstrate their oral and written communication skills.

The text used is *Learning to Program with Matlab: Building GUI Tools* by Lent[4]. A lab manual[5] was created that incorporates some of the NXT exercises documented at Clemson University[6-7]. In the lecture portion an introduction to linear algebra and Matlab concepts are covered. Two laboratory sessions are dedicated to each lab. In the first laboratory session problems are selected from the text[4] and the laboratory manual[5]. The second laboratory session is dedicated to applications using the RWTH programs. Students work in 2 or 3-member groups for Lab 2 through Lab 5. Lab 6 is used to assess the student's ability to create a well-structured program. Both Matlab and Simulink concepts are examined and students work individually. In the last four weeks, students are encouraged to create projects of their own choosing with a restriction that only a small portion of the NXT robot actions already demonstrated in labs 2 through 5 be incorporated. Table 1 shows a schedule of laboratory activities.

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Table 1. Laboratory Activities

Labs	Main Concepts	Applications using the RWTH toolbox
Lab 1	Introduction to the Matlab, plots, formatted printing of data	Introduction to the NXT
Lab 2 (group)	Loops; user-defined functions	Introduction to different sensors; Navigation- forward/backward motion
Lab 3 (group)	Condition Statements; Data files	Obstacle detection and black line follower
Lab 4 (group)	Graphical User-interface (GUI)	Use GUI to command Robot to perform tasks in Labs 3 and 4
Lab 5 (group)	Introduction to Simulink: Embedded Functions, Masks, Subsystems	N/A
Lab 6	Assessment Lab	N/A
Labs 7 – 9 (group)	Open-ended Projects	

LEGO NXT Open-ended Projects

Each group is required to design and program a robot to do a repertoire of actions that extend beyond the maneuvers that were already covered in the labs. All robots must be designed using The LEGO Mindstorms NXT kit 9797; the use of additional LEGO parts is prohibited. Each group is required to create a SolidWorks model of the robot and a Gantt chart. All robots should operate in the autonomous mode. Four projects that were highly ranked by the class are now presented.

Project#1 Time for a Walk[8]: A robot in the form of a dog uses an ultrasonic sensor for its eyes, a sound sensor for the nose, two motors to control the legs, and one motor to control movement of the neck (Figure 1). It is also capable of writing in cursive. The dog moves and rotates its neck

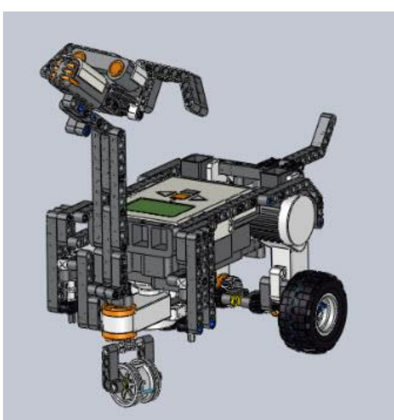

Figure 1. SolidWorks Model of the Dog Robot

Figure 2. Dog writes hello

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through a 180-degree angle, detecting and avoiding obstacles in its path. At the end of the obstacle detection process a pen attached to its side is used to write the word "hello" in cursive (Figure 2.) A graphical user-interface was created to start the robot's actions. The students started with an ambitious idea to program three different actions for the robot. First, have it detect where a loud noise came from and direct itself in that direction. Second, move toward that noise and avoid obstacles along the way. Third, once it reached its destination the robot would stop and demonstrate its intelligence by writing a short word or phrase. However, when the intensity of the sound was very high the while loop in the program would terminate abruptly and the next function, the writing program, would be executed. Due to this unreliable noise detection, the idea was abandoned. Writing was another challenge for the robot. The motor control was unreliable and as the robot performed turns, friction affected the movement of the pen which was mounted on the robot's side. This meant that the algorithm had to be modified several times after observing the response of the robot. Undesirable results were observed when the power and tachometer limits of the motor were low. The team was able to overcome all these difficulties and at the end commented that this was a rewarding experience as it provided an opportunity to apply their freshly learned problem solving skills to design a real physical system.

Project#2 Ronaldo the Soccer Player[9]**:** The idea was to build a robot that would roam a perimeter of a soccer field, look for a ball, retrieve the ball and score a goal (Figure 3.) A light sensor detected boundary lines while ultrasonic sensors detected a ball and the location of the goal. A manipulator made of two forks was attached to the front of the robot and used to guide the ball into the goal. It became a challenge to get the robot to run at a speed that did not affect the performance of the light sensor or the ultrasonic sensors. Another challenge was having the robot make turns at the optimal angles so as to remain within the boundaries. An elliptical shaped playing field allowed for the design of a single turning angle or tachometer limit that kept the robot inside the boundary lines. Figure 4 shows a sample of the Matlab code.

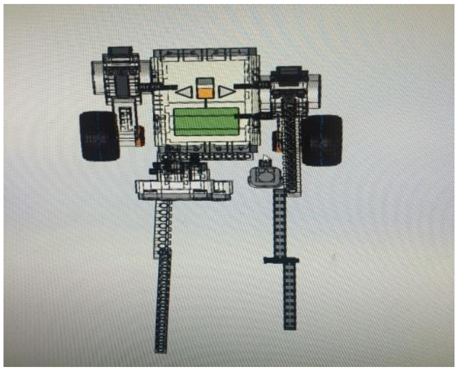

Figure 3. SolidWorks Model of Soccer robot

```
%%  loop to play soccer
while true
   Bound=GetLight(SENSOR_1);
   fprintf(' Bound= %3.0f',Bound)
   Ball=GetUltrasonic(SENSOR_2);
   Goal=GetUltrasonic(SENSOR_3);
   fprintf(' %3.0f', Ball)

   %%  loop to stay in bounds and find ball
   if Bound > 500        %color of black line
      Bound=GetLight(SENSOR_1);
      Ball=GetUltrasonic(SENSOR_2);
      Goal=GetUltrasonic(SENSOR_3);
      RM.Power=-50;
      RM.TachoLimit=0;
      RM.SendToNXT();
      LM.Power=-50;
      LM.TachoLimit=0;
      LM.SendToNXT();
      fprintf('\n ==== %3.0f',Bound)

      %%  loop to find the goal
      while Ball < 6     %distance to ball
         Bound=GetLight(SENSOR_1);
         Ball=GetUltrasonic(SENSOR_2);
Goal=GetUltrasonic(SENSOR_3);
```

Figure 4. Partial Matlab Code for Soccer Robot

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Summary of the concepts used in the program:

- Multiple nested loops inside an infinite loop.
- Conditional statements to check boundary lines.
- Re-declaration of variables in each while loop.
- *fprintf* commands to check sensors that monitor runtime.

This group aimed for a very simple and effective approach in the programming and design phases.

Project#3 Maze Runner[10]: The robot is programmed to traverse a simple maze by employing the left hand rule[11]. This resulted from the idea that if a person is stuck in a maze, by keeping the left hand in contact with one wall of the maze and following that wall consistently, the person will eventually reach the exit.

Figure 5. Rendered SolidWorks Model of the Maze Runner

Figure 6. GUI Control starts Robot's Entrance into the Maze

Two ultrasonic sensors were used for obstacle detection (Figure 5.) One ultrasonic sensor was placed perpendicular to the left side of the robot to sense the wall as a reference point and direct it in a straight line. When the robot got very close to a wall, a quick left turn was performed in order to avoid colliding with the wall. This was followed by rectilinear motion that allows the robot to move forward. The second ultrasonic sensor was placed in the front of the robot so that when it sensed a wall, a head-on collision would be avoided by first stopping and then performing a 90-degree left turn. If the robot were to reach a dead end, it would perform a sequence of stops and turns before driving forward. A challenge was that the Bluetooth connection was not reliable and this interfered with the motion of the robot as it attempted to maneuver the maze. The USB cable was the alternative but this meant that the robot was always tethered to the computer via the 6-ft cable that came with the kit. A solution was to use a USB extension cable (Figure 6.) Another challenge was the lack of understanding of motor tachometer control. During the design process the LEGO NXT would begin to beep uncontrollably after completing a series of maneuvers. This was finally attributed to the limits of the tachometer

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reading not being reset at critical points. Upon overcoming the challenges the design goal was accomplished and the robot successfully traversed the maze.

Project#4 Seek and Destroy[12]: The primary purpose for this robot (Figure 7) was to act as a form of mobile security. The robot would scan its surroundings, detecting only objects within a particular range. Then it would move toward the detected object until it was within an attack range at which point it would stop and fire the weapon. The process was repeated until a maximum of four objects were detected and destroyed.

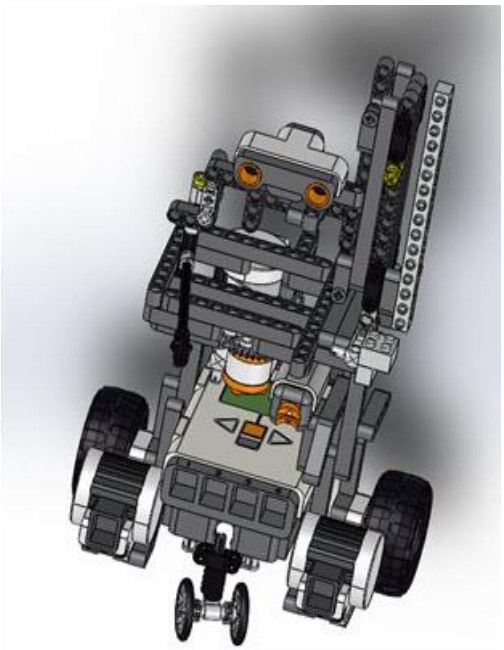

Figure 7. SolidWorks Model of Seek and Destroy Robot

```
for k = [1 4] %Number of targets
  OpenUltrasonic( SENSOR_4 );
  pause( 0.1 );
  %% Searching
  distance = GetUltrasonic( SENSOR_4);
  value=40; %20 inches?
  handles.axes1;
  imshow('Radar.jpg') %GUI displays radar
  while distance>value
     distance = GetUltrasonic( SENSOR_4);
     fprintf('distance is %i \n', distance)  %confirm distance
     SpinAround %Robot rotates
     SearchingText='''Searching''';
     SearchingText2='''...''';
     set(handles.edit1, 'string',SearchingText); %GUI ...
indicates searching status
     pause(1.2);
     set(handles.edit1, 'string',SearchingText2);
     pause(0.8);
  end
  %% Object Detected
  HU=NXTMotor( [MOTOR_B; MOTOR_C]);
  HU.Stop('off'); %Robot stops rotation, prepares for next ...
action
  ObjectDetected='''Target Detected''';
  set(handles.edit1, 'string',ObjectDetected); %GUI ...
indicates target detected status
```

Figure 8. Partial Matlab Code for Search Routine

Three motors, one light sensor, and one ultrasonic sensor were used. In the search phase the robot needed to spin 360 degrees. Two motors were used for the wheels of the robot. The following items were located above the NXT brick: the bullets, the clip to hold the Lego bullets, the club which triggered firing of the bullet, and the light sensor. The ultrasonic sensor served as the eyes of the robot. Gears were added to the motor to increase the firing power of the bullets. This allowed the Lego bullets to fire faster and stronger to knock down the targets. The light sensor acted as a red dot sight which was aimed at the point where the robot would hit the target. The hardest part of the Solidworks model was designing a secure clip holder that would drop the bullets freely and easily. The Lego bullet rested on a platform and the club swung quickly, hitting each bullet in a three-round burst. A GUI was created which was used to start the search process. Figure 8 shows a partial RWTH Matlab code for the search routine.

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Assessment

The weights for the three main categories used for the evaluation of the student's understanding of the material are: laboratory preparatory quizzes (10%), laboratory (50%), short quizzes using clickers (10%), and a project (30%.) Since the fall 2014 semester was the first offering of this course using Matlab, it will be used as a baseline for future semesters. One observation is that all students were able to successfully design and program the robots. There was no situation in which the robots malfunctioned during the robot demonstrations. Projects were completed one week earlier than in previous semesters which allowed students to dedicate more time to final exams. The open-ended projects allowed the students to explore a wider range of projects. The main areas considered in the evaluation of the final project are the powerpoint presentation, the robot demonstration, and the technical report. The instructor critiques the presentations and other class members are encouraged to ask questions of the presenting group. Students are required to implement feedback received during the presentation in their technical report which is due a few days after the presentation. Figure 9 shows the impact of the NXT in the first five labs. The percentage of unacceptable performance in Lab 1 is due to some students not attending the first lab.

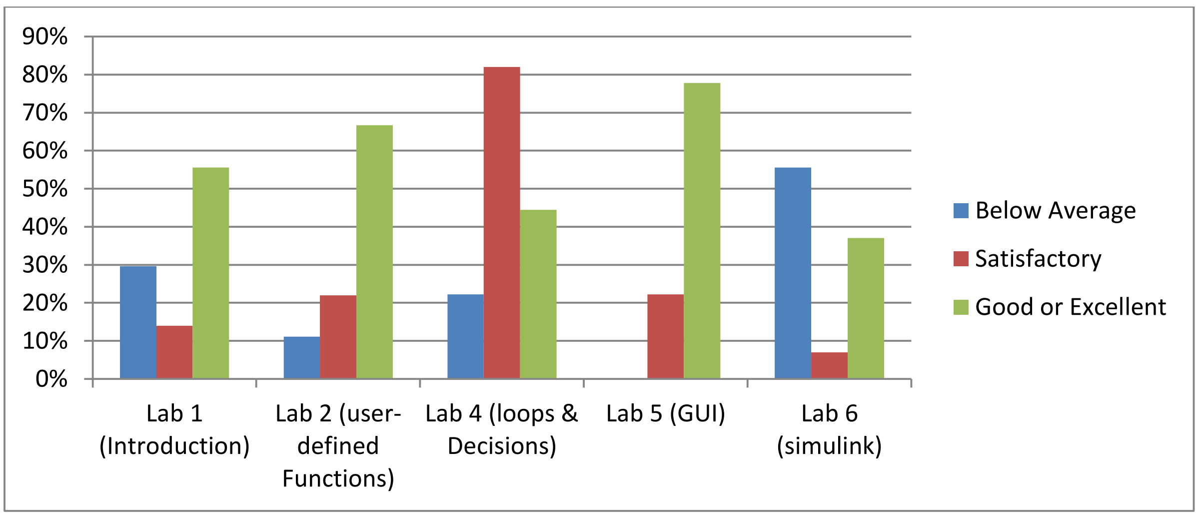

Figure 9. Student Performance in Laboratory Exercises

Lab 6 which concentrates on applied calculus did not incorporate the NXT component. Plans are currently being considered to improve the delivery of Lab 6 as Simulink is used extensively in *Automatic Controls*, a senior-level course for which this course is a prerequisite. Overall the incorporation of the NXT has resulted in a higher passing rate. Every student passed the course.

Assessment of Learning Outcomes

The extent to which students met the course objectives and achieved the desired learning outcomes is shown for three semesters. Laboratory exercises, quizzes, tests, and the final project are used in the assessment (Figure 10.)

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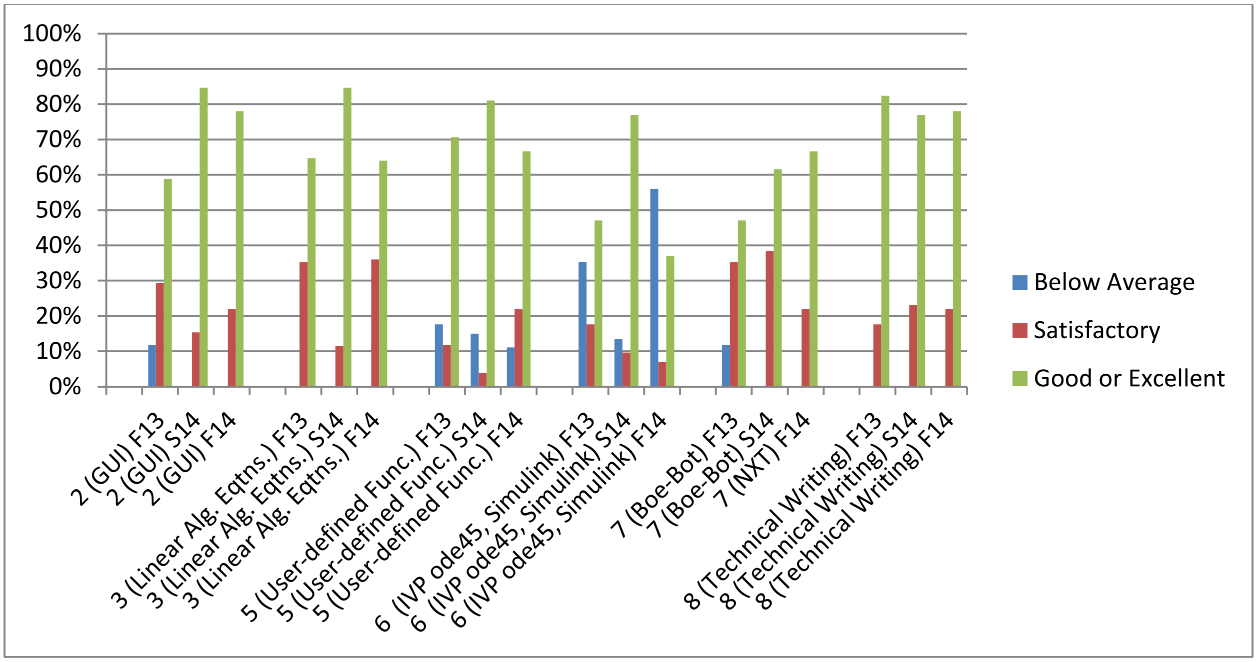

Figure 10. Outcomes for Fall 2013, Spring 2014, and Fall 2014 Semesters

In general, students have difficulty creating user-defined functions although the percentage has been decreasing with 11% of the students showing a weakness in fall 2014. The substantial weakness in solving initial-value problems (IVPs) using the Runge-Kutta method in the Matlab domain and Simulink shown in fall 2014 is being addressed. In spring 2014, clicker quizzes and Lab 6 were used in the assessment of IVPs; in fall 2014, only Lab 6 was used. It can be concluded that multiple modes of assessment should be used to reinforce the concepts and improve the student's ability in this area. However, in order to evaluate each student's proficiency in the application of calculus concepts, Lab 6 will not include group activities. Overall, a high majority of the learning outcomes is satisfied every semester.

Acknowledgments

Project examples presented in this paper were contributed by the following undergraduate students: Jeffrey Bowser, Zebula Doll, Max Elliott, Collin Johnson, Damon Lam, Danielle Lara, Christopher Pelley, Javier Perez-Rodriguez, Reynard Reyes, Daniel Sanchez , Raymond-Andre Siu – Young, and Gabrielle Taylor.

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Work-In-Progress: Enhancing Students' Learning in Advanced Power Electronic Course Using a USB Solar Charger Project

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Abstract

In order to improve students' design and hands on skills in power electronics at Cal Poly San Luis Obispo, a new hardware project has recently been added in the advanced power electronic course. The new project requires students to design and construct a USB solar charger as their final hardware project in the laboratory portion of the course. This work-in-progress paper explains the detail description of the project including design requirements, grading policy, and an example of a completed project.

Introduction

Power electronics is an enabling technology that allows us to convert energy from various types of sources to useful electrical energy. Applications of power electronics therefore cover a wide range of appliances, tools, electronics that we use routinely in our daily lives. For example, many appliances in our house use power electronics due to the need to convert from ac electricity to dc electricity that operates the electronics inside these appliances. Even the latest energy saving LED light bulbs works because their ac input is converted to dc to run the LEDs. Cell phones are also good examples of where power electronics resides since every electronics inside them which operate on several dc voltages are supplied by a single battery. Thus, power electronics is needed here to convert the single dc voltage from the battery to several dc voltage levels for the electronics.

Another reason for the more prevalent use of power electronics is due to the growing interests in renewable energy sources such as solar, wind, and hydropower. Power electronics therefore has become increasingly important where billions of kilo-watts of electrical power are being re-processed every day to provide the appropriate type and level of power needed by loads[1]. As a result, at Cal Poly we have been experiencing significant interest among electrical engineering students in power electronics as indicated by the high enrollments in power electronic technical elective courses[2].

At Cal Poly San Luis Obispo, we offer several technical elective courses in power electronics. Although these courses are mainly for electrical engineering students, they are also open to any non-electrical engineering majors. The following lists these courses with their descriptions[3]:

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EE 410 Power Electronics I
Introduction to power electronics and power semiconductor devices. Analysis, performance characterization, and design of power electronics converters such as: rectifiers, DC choppers, AC voltage controllers, and single-phase inverters. Operation of DC motor drives. Use of commercially available software. 3 lectures, 1 laboratory.

EE 411 Power Electronics II
Switching losses. Analysis, performance characterization, and design of snubber circuits and resonant converters. Operation of DC transmission lines, flexible AC transmission system (FACTS) controllers, three-phase inverters, and AC motor drives. Use of commercially available software. 3 lectures, 1 laboratory.

EE 433 Introduction to Magnetic Design
Design of magnetic components. Fundamentals of magnetics, magnetic cores, design of power transformer, three-phase transformer, dc inductor, ac inductors, dc-dc converter transformer design, actuators. Use of commercially available software. 3 lectures, 1 laboratory.

EE 527 Advanced Topics in Power Electronics
Selected advanced topics in power electronics such as dc-dc converters, phase-controlled rectifiers, switched-mode inverters, ac and dc drives, HVDC transmission, or utility applications of power electronics.

As indicated in the above descriptions, three courses have lab portions where students conduct hands-on experiments in the power electronics lab at Cal Poly throughout the quarter. This hands-on portion of the course is in line with Cal Poly's "learn-by-doing" philosophy. The last course EE 527 is a graduate-level courses with no official lab component. However in the past ten years, students in the course have been assigned a final hardware project where they have to design and build an off-line power supply.

Hardware Project Background

In order to better prepare students for industry, a new final hardware project has been introduced recently in the first two power electronic courses, namely EE 410 and EE 411. These new projects were designed so that students can gain more up-to-date knowledge and applications in power electronics. In the introductory course EE 410 for example, the new final project requires students to build a circuit for dimmable LED lights using surface mount components. With this project, students learn to use a practical switching regulator, to handle surface mount components including soldering skill, to design circuit board layout, and to be familiar with the use of LED lights for energy saving light bulbs[4]. Results from students' assessment on the project show that students felt that the project has indeed helped them in understanding the use and layout considerations of a practical switching regulator, and the project has successfully enhanced their surface mount soldering skill.

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Following the success of the new final hardware project in the introductory course EE 410, there was a need to also update and improve the final project given in the advanced power electronic course EE 411. Initially the EE 411 final hardware project required students to design and build a step-down or buck converter. Assessments conducted on this project indicated that the project successfully improved students' ability to apply their knowledge gained from the previous power electronic class, and also enhanced students hands-on skills related to testing and measurement skills in dc-dc converter design. The one aspect that students found lacking was the practicality of the project. They wanted to further learn how their circuit could be useful in real world. A new final hardware project was therefore developed to add this component in the hardware project, and introduced into the advanced power electronic course EE 411 in Winter 2013.

The Hardware Project

The EE 411 course covers advanced concepts, techniques and practices in power electronics. Just like EE 410, the course has lecture and laboratory components that enforce both concepts and practical skills. In the laboratory portion of the course, students conduct simulation and hardware based experiments to verify several concepts learned in the lecture and to sharpen their hands-on skills. To complement the existing laboratory experiments, a new final hardware project has recently been introduced as a culminating design experience for the class. The project entails the design and construction of a step-down converter that utilizes a solar panel as the energy source and a USB connector as the output. During the demonstration of the project, a cell phone will be connected to the output of the converter to show whether the converter is functional when its input is tied to a solar panel exposed to sunlight.

There are several objectives aimed for introducing the project. First, the project trains students to design the converter from the ground up. A set of design requirements is provided to students as listed below:

Requirements:
- The circuit should be built on either a proto-board (provided by instructor) or a PCB (at your own expense), and the use of breadboard is not allowed for final demonstration
- Continuous conduction mode down to 20% load
- Nominal Input Voltage is 15 V, but must be able to handle maximum input voltage of 22 V
- Nominal Output Voltage is 5 V at 10 W maximum
- Peak to peak output voltage ripple at full load must be < 5%
- Efficiency at full load ≥ 80%. At the time of the demo, an efficiency plot (showing 20% to 100% of load in steps of 10%) should be made available to the instructor.
- Load regulation at nominal input with 10% to 90% load ≤ 3%
- Line regulation at full load with input changed from 12 V to 18 V ≤ 1%
- Input terminals must use banana female plugs provided by the instructor
- Output terminals must use a USB 2.0 connector also provided by the instructor

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Secondly, the project provides students with the learning experience in designing a widely used power electronic circuit while applying the knowledge they have learned from the previous power electronic class. Third, the project sharpens students' testing and troubleshooting skills since they will test their circuit board by utilizing standard industry lab test equipment. Lastly, the project offers the opportunity for students to be familiar with using a solar panel as the energy source and interfacing it with a real circuit that can charge a USB device.

To do the project, the class is divided into groups of 2 to 3 students. To help guide students in the process, several milestones and deadlines are provided to them. For example, by the second week of the quarter, each group must have already completed their converter circuit design and component sizing which have to be approved by the instructor. By the end of the third week, each group must submit a Bill of Materials which again has to receive approval from the instructor before they can proceed with purchasing the components. To ensure that the instructor can monitor the progress made by each group and to allow students to have technical discussions with the instructor, every week one hour out of the three hour lab time is allotted for students to conduct their project in the power electronics lab. Beyond the assigned lab time, the power electronics lab is available for students to continue their project. During the 10th week of the quarter (the week before the finals week), students will have to demo their project in the lab against all design requirements in front of the instructor. The project is worth 15% of the overall final grade for the class, and each member of a group will receive the same grade on the project based on how well their converter meets the specifications listed previously. Since its inception, the project has been supported by Enerpro Inc. such that each group may have up to $50 reimbursable expenses toward the project. Figure 1 depicts a completed converter (left) and the same converter connected to a solar panel to charge a cell phone (right).

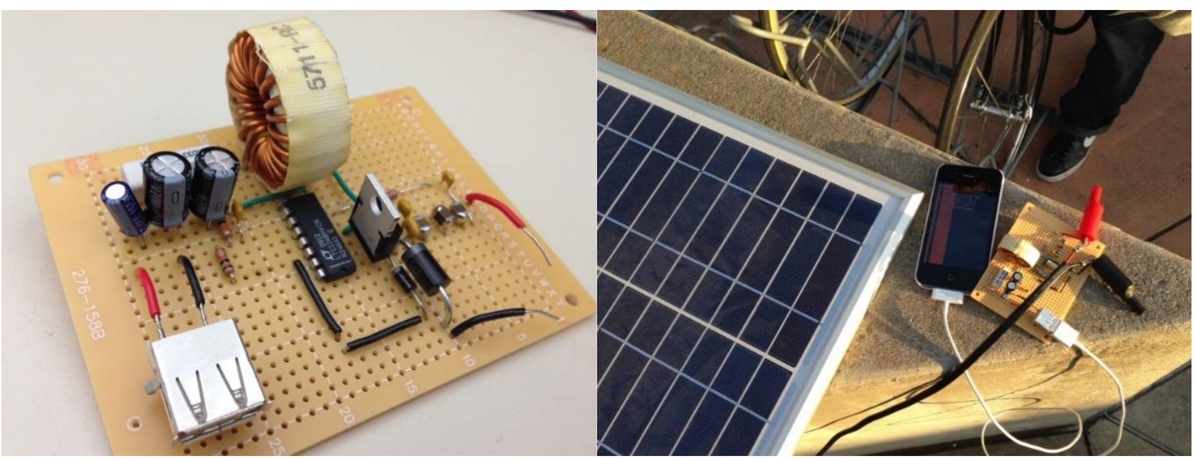

Figure 1. A completed converter board (left), and the converter in action (right)

Conclusion and Further Work

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This paper presents a new hardware project assignment introduced in the second course of power electronics at Cal Poly San Luis Obispo. The project has the main goal of enhancing students' hands-on and practical experience so that students will be better prepared once they enter the work force. It is interesting to note that even at the first phase of the project, students were observed to have the difficulties in finding the right controller chip for their project. This further emphasizes the importance of this project since knowledge on various switching regulator controller chips is a practical skill generally sought by companies when they are looking to hire new graduates with power electronic background. From the instructor's point of view, assigning such a project requires significant amount of time throughout the quarter. Students' assessment on the project is currently being planned to evaluate how effective the project is in helping to achieve the learning outcomes of the course.

Acknowledgment

The author wish to thank Enerpro Inc. for providing the financial support for the USB Solar Charger project conducted in EE 411 class at Cal Poly San Luis Obispo.

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Geostatistical analysis of geotechnical parameters

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Abstract

Application of various techniques for statistical analysis to the field of civil engineering is well documented. In this paper a case study is presented, where kriging is applied for producing a map showing the probability that the existence of collapsing soil at certain depth of Tucson, Arizona area exceeds a critical threshold value. The assessment is based on existing criteria with spatial analysis used to build up model for low, medium and high collapse potential.

Key words: Map, variogram, kriging, collapsing, soil.

Introduction

Understanding the spatial distribution of data from phenomena that occur in space constitute a great challenge. Due to availability of high speed computing system such studies are becoming common in almost every field of study, such as health, environment, geology, engineering, and many others. Besides visual perception of the spatial distribution of the phenomenon, the analysis is useful to translate the existing patterns in to objective and measureable quantities by estimating parameters at an unknown location. Since the emphasis of spatial analysis is to measure properties and relationship, taking in to account the spatial localization of the phenomenon under study, such analysis may be used for geotechnical parameters. Spatial analytical technique, known as geostatistics may be useful for this purpose. Geostatistical technique of simple indicator kriging can be used with the probabilistic model to develop the probability contour with the contour of estimation variance.

A soil deposit in a region may be either residual or transported. Also a transported soil may be either *alluvial* (stream borne) or A*eolian* (wind borne) or *colluvial* (gravity transported). When alluvial soils are deposited in an arid or a semi-arid environment, they develop larger voids and undergo a large decrease in bulk volume upon saturation or load application and are known as collapsing soils. However, it is difficult to identify collapse susceptible soils with this definition due to the existence of many different types of clay minerals and many other factors that contribute to the collapse phenomenon. Therefore geostatistical methods in analyzing collapsing soil parameter would provide an optimum solution.

In this study geostatistical techniques of simple kriging were applied to selected collapse criteria and collapse-related soil parameters for soil in Tucson, Arizona. Previous works on this topic was limited only to studies involving either specific areas or specific soil parameters. The purpose of this study was to gather as much information as possible from reliable sources and to use this data

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with statistical techniques, such as regression and factor analysis, to determine the variation of selected collapse criteria and collapse-related soil parameters in three dimensions.

Mathematical Details:
Kriging is a geostatistical technique to interpolate the value $Z(x_0)$ of a random field $Z(x)$ at an unobserved location x_0 from observations $z_i=Z(x_i)$, $i= 1,\ldots n$ of the random field at nearby locations $x_1,\ldots,x_n$. Kriging computes the best linear un biased estimator $\hat{Z}(x_0)$ based on a stochastic model of the spatial dependence quantified either by the variogram $\gamma(x,y)$ or by the expectation $\mu(x)=E[Z(x)]$ and the covariance function $c(x,y)$ of the random field.

The kriging estimator is given by a linear combination $\hat{Z}(x_0)=\sum_{i=1}^{n} w_i x_0 Z(x_i)$ of the observed value $z_i=Z(x_i)$ with weights $w_i(x_0)$,

$i=1,\ldots,n$ chosen such that the variance, known as kriging variance or kriging error

$$\sigma_k^2(x_0):$$
$$=Var\left(\hat{Z}(x_0 - Z(x_0\right)$$
$$=\sum_{i=1}^{n}\sum_{i=1}^{n}\ \sum_{j=1}^{n} w_i(x_0)w_j(x_0)+$$
$$Var(Z(x_0))-$$
$$2\sum_{i=1}^{n} w_i(x_0)c(x_i,x_0)$$

is minimized subject to the unbiasedness condition:

$$E[\hat{Z}(x)-Z(x)=\sum_{i=1}^{n} w_i(x_0)\mu(x_i)-\mu(x_0)=0$$

The kriging variance must not be confused with the variance

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$$Var\left(\hat{Z}(x0)\right)$$
$$= Var\left(\sum_{i=1}^{n} w_i Z(x_i)\right)$$
$$= \sum_{i=1}^{n}\sum_{j=1}^{n} w_i w_j c(x_i, x_j)$$

Of the kriging predictor $\hat{Z}(x_0)$ itself

The kriging weights of simple kriging have no unbiasedness condition and are given by simple kriging equation system:

$$w = cc(0)$$

Where

$$w = \begin{pmatrix} w_1 \\ \vdots \\ w_n \end{pmatrix}$$

$$c = \begin{pmatrix} c(x_1, x_1) & \cdots & c(x_1, x_0) \\ \vdots & \ddots & \vdots \\ c(x_n, x_1) & \cdots & c(x_n, x_n \end{pmatrix}^{-1}$$

$$c(0) = \begin{pmatrix} c(x_1, x_0) \\ \vdots \\ c(x_n, x_0) \end{pmatrix}$$

Simple kriging interpolation:
The interpolation by simple kriging is given by

$$\hat{Z}(x_0) = \begin{pmatrix} z_1 \\ \vdots \\ z_n \end{pmatrix}' \begin{pmatrix} c(x_1, x_1) & \cdots & c(x_1, x_n \\ \vdots & \ddots & \vdots \\ c(x_n, x_1) & \cdots & c(x_n, x_n) \end{pmatrix}^{-1} \begin{pmatrix} c(x_1, x_0 \\ \vdots \\ c(x_n, x_n) \end{pmatrix}`$$

The kriging error is given by:

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$$Var\left(\hat{Z}(x_0) - Z(x_0)\right)$$
$$= \underbrace{c(x_0, x_0)}_{Var(Z(x_0))} -$$
$$\underbrace{\begin{pmatrix} c(x_1, x_0) \\ \vdots \\ c(x_n, x_1) \end{pmatrix}' \begin{pmatrix} c(x_1, x_1) & \cdots & c(x_1, x_n) \\ \vdots & \ddots & \vdots \\ c(x_n, x_1) & \cdots & c(x_n, x_n) \end{pmatrix}^{-1} \begin{pmatrix} c(x_1, x_0) \\ \vdots \\ c(x_n, x_0) \end{pmatrix}}_{\text{var}(Z'(x))}$$

Which leads to the generalized least squares version of the Gauss-Marcov theorem[1].
$$Var\left(Z(x_0)\right) = Var\left(\hat{Z}(x_0)\right) + Var\left(\hat{Z}(x_0) - Z(x_0)\right)$$

ORDINARY KRIGING EQUATION

The kriging weights of ordinary kriging fulfill the unbiasedness condition

$$\sum_{i=1}^{n} \lambda_i = 1$$

and are given by the ordinary kriging equation system:

$$\lambda = \gamma\gamma^{-1}\lambda^*$$

where

$$\lambda = \begin{pmatrix} \lambda_1 \\ \vdots \\ \lambda_n \\ \mu \end{pmatrix}$$

$$\lambda^{-1} = \begin{pmatrix} \gamma(x_1, x_1) & \cdots & \lambda(x_1, x_n) & 1 \\ \vdots & \ddots & \vdots & \vdots \\ \lambda(x_n, x_1) & \cdots & \lambda(x_n, x_n) & 1 \\ 1 & \cdots & 1 & 0 \end{pmatrix}^{-1}$$

$$\lambda^* = \begin{pmatrix} \lambda(x_1, x* \\ \vdots \\ \lambda(x_n, x*) \\ 1 \end{pmatrix}$$

The additional parameter μ is a Lagrange multiplier used in the minimization of the kriging error $\sigma^2_k(x)$ to honor the unbiasedness condition.

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The interpolation by ordinary kriging is given by

$$\hat{Z}(x^*) = \begin{pmatrix} \lambda_1 \\ \vdots \\ \lambda_n \end{pmatrix}' \begin{pmatrix} Z(x_1) \\ \vdots \\ Z(x_n) \end{pmatrix}$$

The kriging error is given by

$$\operatorname{var}\left(\hat{Z}(x^*) - Z(x^*)\right)$$

$$= \begin{pmatrix} \lambda_1 \\ \vdots \\ \lambda_n \\ \mu \end{pmatrix}' \begin{pmatrix} \lambda(x_1, x^*) \\ \vdots \\ \lambda(x_n, x^*) \\ 1 \end{pmatrix}$$

COLLAPSE CRITERIA AND RELATED PARAMETERS

In arid regions soil deposits become partially saturated with large voids due to high evaporation rate. Application of loads on such soils causes small deformation at low degree of saturation. However as soon as the soil becomes saturated, large deformations take place due to the collapse of the intergranular structure and the phenomenon is referred to as collapse. In general, if the dry density of the soil is sufficiently low to give a void space larger than that required to hold the liquid limit water content, then collapse upon saturation is likely. Otherwise collapse generally occurs only when the soil is loaded.

Collapsing soils has been recognized in Africa, part of Asia, Europe as well as in the United States. In the United States the severity of the problem has been observed in the Midwestern and Western United States, where soil deposits are generally either *aeolian* or *alluvial.*

Many criteria for predicting the collapsing potential of a soil are available in the literature (Ref from ASCE). Some of the criteria are derived theoretically from consolidation test results and some are empirical. The methods for evaluating collapse susceptibility vary from simple to very complex. Considerable effort has been given to establish criteria for predicting the collapse potential and the critical values for severity of a soil. Some of the more commonly used criteria are described below.

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The parameter C_p is known as collapse parameter and is obtained from consolidation test as shown in Fig. 1. (Jennings and Knight, 1957)

$$C_p(\%) = \frac{\Delta e_c}{1+e_0} \times 100 = \frac{\Delta H_c}{H_0} \times 100 \qquad (1)$$

Where Δe_c and ΔH_c are changes in void ratio and sample height after saturation under a pressure of 200 kPa, and H_0 is the initial height of sample

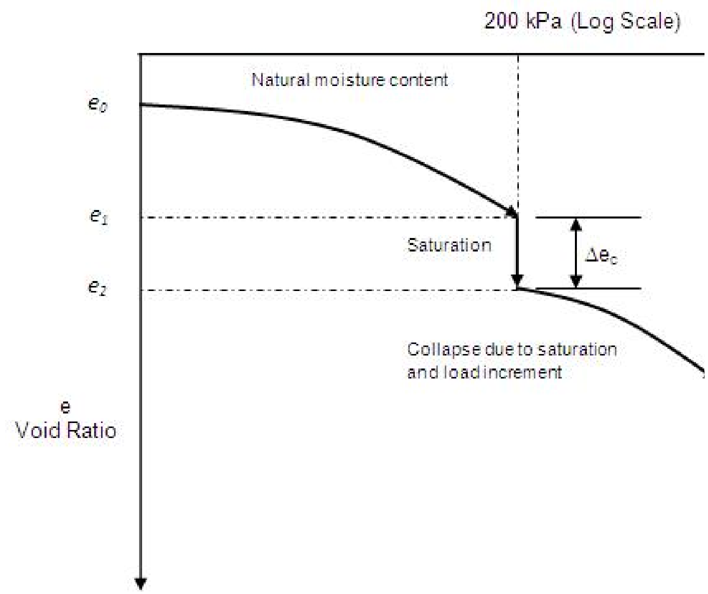

Fig. 1. Typical collapse potential in one dimensional consolidation test

Sabbagh(1982).
R, known as Gibb's parameter is obtained from the following relation:

$$R = \frac{\frac{\gamma_w}{\gamma_d} - \frac{1}{G_s}}{w_l} \qquad (2)$$

Where γ_d is the dry unit weight, w_l is the liquid limit moisture content, γ_w is the unit weight of water, and Gs is the specific gravity of soil solids

Denisov's (1964) criterion of collapse susceptibility is expressed as the ratio e/e_{LL}. If the ratio is greater than 1 then the soil is collapse susceptible.

e_{LL} is the void ratio at liquid limit and e is the void ratio at natural moisture content.

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Beside the established criteria for soil collapse, there are other parameters that contribute to collapse phenomenon. These related parameters are: initial dry unit weight (γ_d), initial moisture content (w_0), initial void ratio (e_0), initial porosity (n_0), initial degree of saturation (s_0) and plastic limit (*PL*). Specific cut-off values for selected parameters are given below in Table 1

Table 1.Critical Values for and High Collapse (HC) Medium Collapse (MC) and Non-Collapsing(NC), Soil Parameters.

Param.	(HC)	(MC)	(NC)
C_p (%)	> 5	$2 < C_p \leq 5$	≤ 2
R	≥ 1.4	$1.0 \leq R < 1.4$	< 1.0
e_0	≥ 0.82	$0.67 \leq e_0 < 0.82$	< 0.67
γ_d,(kN/m^3)	≤ 14.3	$14.3 < \gamma_d \leq 15.6$	> 15.6

For this study field and laboratory test data were collected from local consulting engineers' offices and from the reports of previous researchers (e.g. Sabbagh, 1982). The raw data were reduced to obtain parameters in two categories: established criteria, such *as* C_p, R, and collapse-related soil parameters, such as, γ_d, w_0, e_0, n_0, s_0 and *PL*. Analysis performed on selected parameters are presented in this paper.

Modeling of variogram:

Modelling of variogram is the first and most important step in applying the technique of kriging, which is the method used here for obtaining unbiased estimate of parameters in un sampled location. A considerable amount of computation is necessary to obtain an adequate estimate of the variogram because of the empirical and subjective nature of the estimation process[3]. Parameters of interest with critical values are listed in Table 1. The various data sets containing number of data points of the parameters are listed in Table 2.

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Table 2. Data sets used in the Analysis

Data set Numer	Range of depth, m	Number of Data
1	0.0-0.3	125
2	0.3-0.6	286
3	0.6-0.9	254
4	0.9-1.2	100
5	1.2-1.8	104
6	1.8-12.2	123
7	0.0-12.2	219

Representative variograms were obtained for each of the parameters in each of the seven data sets, but only few are presented here. Since modeling of a variogram is, in part, an art requiring some subjective judgment, multiple trials are usually necessary in order to obtain a satisfactory variogram. The important parameters for a variogram are the range of influence, a, and the sill C in a nested model as given below.

Nested Model:

$$\gamma(h) = C\left[\frac{3h}{2a} - \frac{1h^3}{2a^3}\right] + C_0 \quad for\ h < a \qquad (3)$$

$$= C + C_0 \qquad \text{for} \qquad h \geq a$$

and $$\gamma(0) = C_0 \qquad \text{for} \qquad h = 0$$

In geostatistical modeling, the most commonly used model is the nested models as shown in Figure 2. This model bears the same significance as the Normal distribution bears to statistics.

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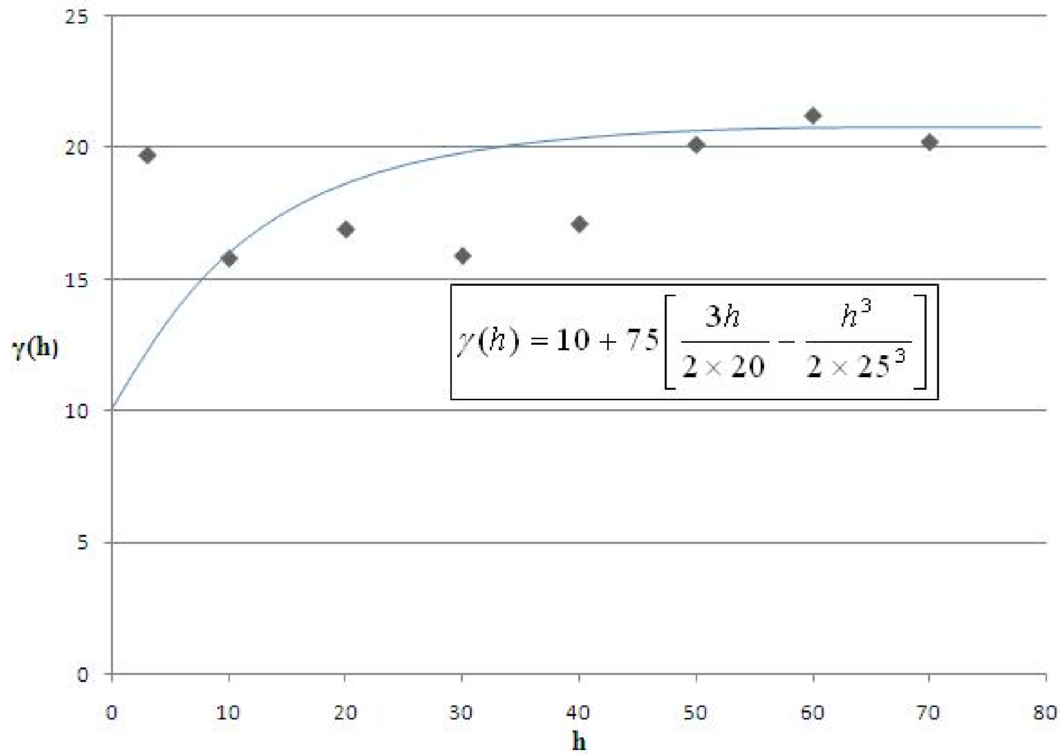

Fig.5. Semi-variogram and fitted equations for Cp of Data Set 5

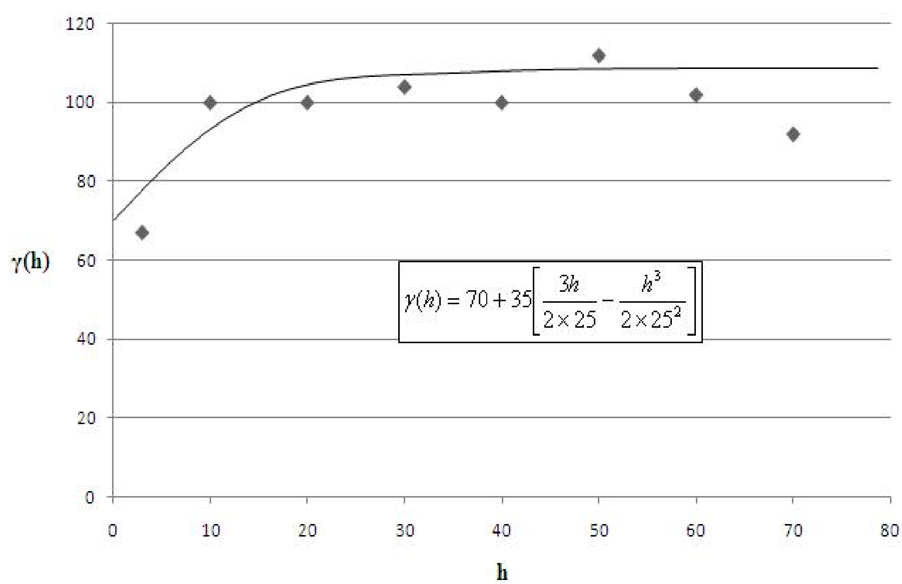

Fig.6. Semi-variogram and fitted equation for dry density of Data set 5.

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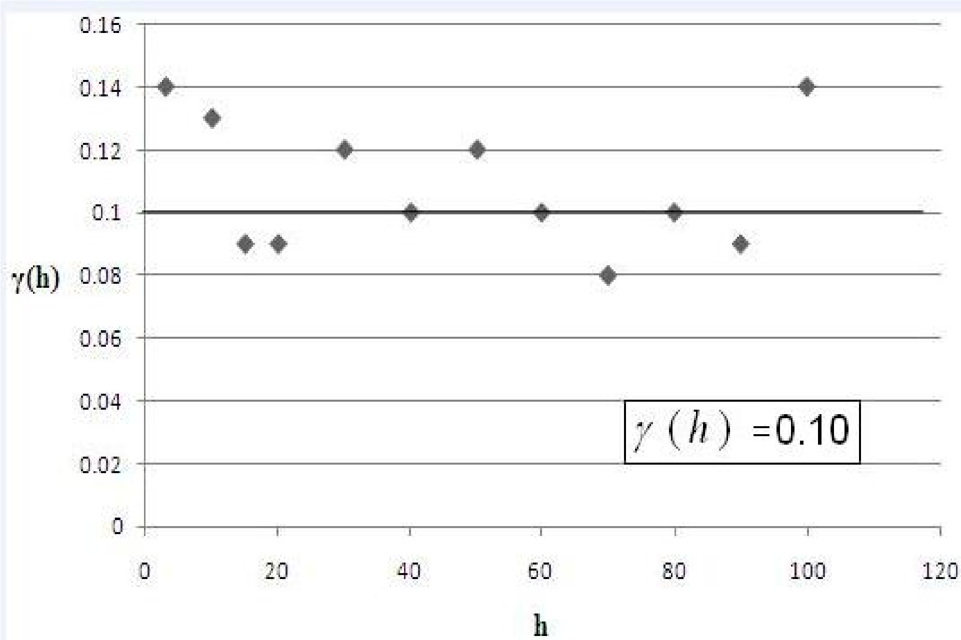

Fig.7. Semi-variogram and fitted pure nugget model for initial void ratio of Data set 6

Variograms were obtained for the analysis for all the parameters, however few of them are presented here. Figures 3 and 4 show the variograms for C_p and γ_d of data set 5, respectively. In several cases a pure "nugget effect" model was obtained, indicating a complete lack of geological structure, Figure 5, shows such a model for the parameter e_0 of data set 6.

Fitting a Model

Constructing a variogram is to find theoretical model that best fits the experimental variogram. The choice is often limited to linear or spherical models, with a spherical model being the most common as the parameters are estimated subjectively. However, it is important that the chosen theoretical model y(h) fits well to the experimental semi-variogram within the model's limits of reliability[5]. The choice of a theoretical model is generally made by examining the experimental variogram and taking in to account the fact that variograms are subject to significant fluctuations at large distances. Since most of the experimental variograms could be approximated by a spherical model, such a model was fitted to all the computed variograms in this study.

The key parameters of the selected spherical model, after cross-validation with different trial models for Data set 1 are presented in Table 3. The nugget value C_0 which is the estimate of y at h=0, provide an indication of short distance variation. The greater the value of C_0, the greater is the variance of the data set. Some of the model, e_0, for example shows a "pure nugget" effect indicating lack of spatial correlation.

Table 3. Parameters of Spherical Models fitted to Data Set 2.

Data Set	Parameter	Nugget C_0	Range, a	Sill C
2	C_p	18.5	-	-
	γ_d	12.5	35.0	100.0
	n_0	32.4	35.0	45.0
	s_0	102.0	30.0	148.0
	w_0	0.002	25.0	0.0025
	e_0	0.042	30	0.053

The range, a, of the variogram can be interpreted as the diameter of the zone of influence which represents the average maximum distance over which a soil property is spatially related. In our study this distance was found to be 5.5 to 8 miles which is large relative to the distance over which soils are usually sampled for laboratory tests for a particular project, This suggest that , geostatistical concept can be applied successfully to the study of geotechnical problems.

There are three methods of kriging: punctual, block, and universal. Puntual kriging, which provides estimates for values of a random variable at points where there is no drift, has two forms: simple kriging if the mean value of the variable is known, and ordinary kriging, if the mean value is not known. Drift is defined as a non-stationary expectation of a random function. Block kriging is used when an estimation of the spatial average is required over a volume or an area. Universal kriging is an optimal method of interpolation that applies in all cases where drift must be taken in to account because of lack of data to make stationary or quasi-stationary estimates.

In this study, variograms were estimated for each collapse criterion and collapse related soil parameters (Table 1) using a discrete number of values obtained from test data at incremental distances corresponding to sampling locations throughout the area. These variograms (Table 3) are then used in conjunction with ordinary kriging to estimate values of the parameters at un-sampled locations. Indicator kriging[6] was then utilized to produce contour plots of estimated probability and associated kriging variance for each parameter in each data set.

Results and discussion

Results of analyses showing probability contour of high collapse potential with estimation variance are shown are in Fig 6 (a) and 6(b). The shaded zones show areas where there is a 60%-80% probability of encountering collapse susceptible soil. The variance of estimation is seen to lie within a range of 0.5 and 0.6. Similar plots were developed for all of the other collapse criteria and collapse-related soil parameters for each of the seven data set, however, they are not presented here.

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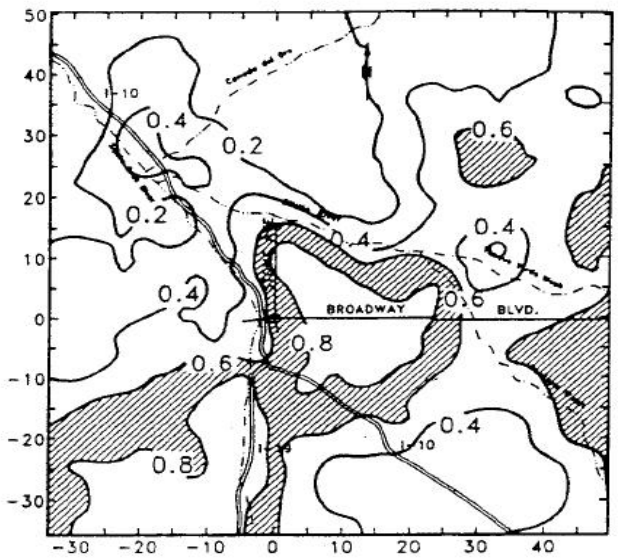

Fig. 6(a) Probability Contour showing areas of high collapse potential

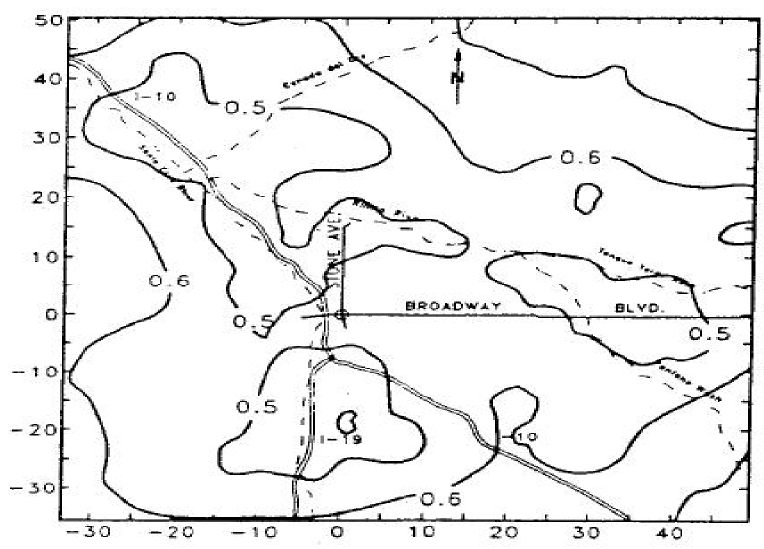

Fig. 6(b) Contour showing estimation variance of estimating probability of high collapse potential

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Conclusions

The following conclusions are logically made from the foregoing discussions:

1. Collapsing soil parameters can be considered as regionalized variable and the concept of geostatistics is applicable.

2. Linear estimation method of kiriging was found to be a valuable tool for characterizing and modeling the spatial variability of geotechnical parameters.
3. The parameters under investigation can be best be fitted by a spherical model variogram
4. Simple Kriging methods can be used to develop probability contour with estimation variance for selected soil parameters at. This information is extremely valuable to planners and Government officials.

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Engaging Female and Underrepresented Community College Students through Humanitarian Engineering and Context Based Learning Pedagogies

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Abstract

It is a known fact that female and underrepresented ethnic groups (African American, Hispanic, Pacific Islanders and Native Indians) are scarce in Engineering Classrooms. These demographic groups also have rather high attrition rates on Engineering Courses. At Ohlone College, we found that Engineering for Humanitarian/Social Change classroom projects increased retention, commitment and academic success amongst female and ethnically underrepresented students. Our pedagogy is based on Context-Based Learning (CBL) Service Based Learning (SBL). Therefore, we discuss data collected over four semesters that suggests that the integration of Context-based learning (CBL) and Service based Learning(SBL) through Engineering for Humanitarian and Social Change projects, could indeed increase the number of female and ethnically underrepresented students in Engineering classrooms. We also discuss our NSF-UC Berkeley funded collaboration on Context-Based Learning and the IEEE Santa Clara Section's support for Engineering for Humanitarian and Social Change Projects at Ohlone College.

Female and Underrepresented Ethnic Group Students in Engineering

To continue advancement in energy science and research and to thrive in a global economy, the U.S. will have to rely on scientists and engineers to develop innovative and high-value-added products and services, as well as improve productivity through the use of technology-based tools.[1] This pipeline of scientists and engineers, with its under-representation of women and underrepresented minorities (African Americans, American Indians or Alaskan Natives, and Hispanic Americans), is a critical concern for the U.S.[2] In 2010, the National Academies of Science reported that underrepresented minorities "embody a vastly underused resource and a lost opportunity for meeting our nation's technology needs".[3] With today's society facing global challenges in energy that are essential to sustaining our current way of life, it is even

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more critical for 4-year institutions to reach out to pools of students traditionally underrepresented in science and engineering programs.

One pool of such students is community college students pursuing math, chemistry, and physics courses that are transferrable to baccalaureate programs. In a Strategy for American Innovation, the Obama administration stated that “President Obama is taking continuous steps to improve our educational system ... and to promote student achievement and careers in STEM fields”, and “the Administration is committed to restoring America’s global leadership in college graduation rates ...., making investments in community colleges ....”[4,5] With more resources being allocated to community colleges to stimulate student achievement in STEM fields, and community colleges serving many ethnic and racial minorities, community college students are uniquely positioned to fill the pipeline of STEM professionals.

With enrollment in the nation’s community colleges hitting an all-time high, students from these institutions are a rich source of the nation’s recipients of undergraduate and graduate degrees in STEM fields. The community college transfer pathway is particularly important for African American, Hispanic and Native American STEM degree recipients, as well as low-income students due to its low cost ($36/unit).[6] In this time of high unemployment and economic crisis, as in earlier recessions, community college enrollment has surged. During the 2009-2010 academic years, California alone enrolled 2.7 million students. The California Community College System (CCCS) is the largest community college system in the U.S., serving 25% of the nation’s community college students.[7] Of the students enrolled for 2009-2010, 40% were from NSF-categorized underrepresented minority backgrounds. In fall 2009, nearly 50,000 CCCS students transferred to University of California (UC) or California State University (CSU) campuses[8]. One year earlier, nearly 20% (3,344) of all UC B.S. degrees in STEM fields were earned by community college transfer students, but only 11% (356) of these transfer graduates were from underrepresented minority backgrounds; 40% were women.[6] According to in 2015 fifty-five percent of community college students are people of diverse ethnic backgrounds and roughly 53 percent are female.[6]

Despite the relatively significant number of female and ethnic minority students in the CCCS we see a disproportionately low number in the STEM fields. Therefore, there is the need to adapt our classroom pedagogies to engage these demographic groups of students.

Context Based Learning Pedagogy

The Obama Administration has forecasted that over the next decade, the U.S. economy needs approximately 1 million more STEM professionals than the U.S. will produce at current rates.[9]

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In February 2012, the President's Council of Advisors on Science and Technology (PCAST) issued an undergraduate STEM education report indicating fewer than 40% of students who enter college intending to major in a STEM field complete a STEM degree. Increasing the retention of STEM majors from 40% to 50% would alone generate three-quarters of the targeted 1 million additional STEM degrees over the next decade. With the first two years of college being the most critical years for the recruitment and retention of STEM majors, it is imperative to focus actions on methods that influence the quality of STEM faculty and adopt teaching methods supported by evidence derived from experimental learning research.

Research has found that high-performing students frequently cite uninspiring introductory courses as a factor in their choice to switch majors.[10] Empirical evidence about how people learn and assessment of outcomes in STEM classrooms all point to a need to improve teaching methods to enhance learning and student persistence.[10] However, a significant barrier to broad implementation of evidence-based teaching approaches is that most faculty lack experience using these methods and are unfamiliar with the vast body of research indicating their impact on learning. This gap in experience has resulted in STEM education lacking relevance to a student's life, where STEM classes traditionally teach sets of scientific and engineering principles and concepts with little course time devoted to exploring the application of principles and concepts in real-world context or technology implications.[11] Additionally, scientific principles are typically taught in scientific discipline silos, without real-world application that can span more than one scientific discipline.

Responding to the challenges identified in the PCAST report, UC Berkeley created a research experience program for community college faculty, called **RET in Engineering and Computer Science Site: UC Berkeley's Context-Based Research Experience for Community College Faculty** *(also referenced as the UCB Context-Based RET Site in this article)* that offered community college faculty a nine-week experience that integrated individual hands-on research with team-based curriculum development to enable new research concepts to be introduced in community college classrooms in the *context-based approach*. Closely aligned with project-based learning and inquiry-based science education, the context-based approach was selected to provide the participants a pedagogical method that brings their research experience alive in the community college classroom by tying the teaching with applications that students can relate to in their lives.[12] The *context-based approach* has been shown through assessments to enhance the students' interest in STEM and has been applied successfully in college teaching, particularly to the teaching of chemistry[10,12]. Empirical evidence has also shown that context-based education helps students see and appreciate more clearly the links between science and everyday lives.[13,14,15] The context selected for this RET program was technology applications that offer societal benefits and have employment opportunity potential. The premise is that using such context will

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increase community college student engagement in STEM studies, thereby contributing to student persistence and eventually, improved retention rates of students in STEM.

RET NSF-UC Berkeley Funded Collaboration on Context-Based Learning

The primary goal of the UCB Context-Based RET Site was to provide a professional development experience for community college faculty that:

- Engages community college faculty in research of current engineering topics;
- Promotes literacy in applications of their research topics;
- Guides faculty to develop and teach context-based science and engineering lessons that connect science and engineering concepts to practical applications;
- Enables community college students to connect their STEM education to exciting careers;
- Builds a vibrant network of community college faculty, faculty, postdoctoral, and graduate student researchers that results in long-term collaborative partnerships; and
- Disseminates online context-based training modules that can contribute to the scientific and engineering literary of community college faculty and the general public.

To deliver on these goal and objectives, the UCB Context-Based RET Site was a nine-week summer experience, consisting of three elements: independent research, team-based curriculum development, and professional development seminars. The UCB Context-Based RET Site was based on a context-based model, where the *context* is a technology application, rather than a focus on a particular research concept.

Program Design: During the summer program, 4 community college faculty participated in a 9-week experience, with 8 weeks focused on research, and 1 week focused on curriculum development. Each faculty's experience consisted of three elements:

Independent Research: Each community college faculty member conducted an independent 8-week research project in an engineering research group in which faculty, postdoctoral researchers, and graduate students were involved in existing research.

Team-based Curriculum Development: The community college faculty designed and developed teaching modules that linked the technology focus area with the concepts from the research of each team member. The design and some development activities for the teaching modules ran concurrent with research. The faculty transitioned into fulltime curriculum development during the ninth week of their fellowship. UC Berkeley's Center for Teaching and Learning also supported the faculty in the design and development of the teaching modules.

Professional Development: Community college faculty participated in a research orientation, training in research protocol, laboratory safety, and scientific ethics, group meetings, and seminars on context-based pedagogical methods and online education.

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Together, this breadth of summer experience made this a broad learning experience that took full advantage of the strengths of the university.

Green and Sustainability Manufacturing

Manufacturing is an unlikely first choice for a profession among college students. Nevertheless, in the 2012 State of the Union address, President Obama gave a blueprint for an economy that is built to last based on American manufacturing.[16] The manufacturing sector has driven knowledge production and innovation in the U.S. by supporting two-thirds of private sector research and development and by employing scientists, engineers, and technicians to invent new products and introduce innovations in existing industries[17]. After several decades of decline, early signs of manufacturing returning to the U.S. reflect the changing of conditions.[18,19,20] Resurgence will only be realized with sustained cost competitiveness and innovation. Reducing environmental impact, utilizing resources more efficiently and, overall, greening the technology of production are elements in lean manufacturing. At many levels, substantial process improvements can be made to reduce energy and resource consumption. But there is also potential in manufacturing enhancements that have a larger impact on the life cycle impact of the product the manufactured item is used in. This is referred to as leveraging and identifies manufacturing-based efficiencies in the product that are due to improved manufacturing capability but which, in the long run, have their biggest effects on the lifetime consumption of energy or other resources or environmental impacts.

Community college faculty participating in the green and sustainability manufacturing topic will learn how design and manufacturing practice can influence sustainability, including analysis of process and system effects and consider the social impacts of manufacturing. Specific topics for research projects included:

- Defining metrics for sustainability in manufacturing
- Green supply chains
- Linking social impacts to design and manufacturing decision-making
- Material selection (green chemistry and materials) in manufacturing
- Case studies in green manufacturing practice

Pedagogy of Humanitarian Engineering in the Introduction to Engineering Class

Engineering education could be said to be at a crossroad, with educators and researchers calling for new ways to understand engineering's social role. Two approaches to engineering education that are relevant to the social context of engineering have emerged. First, there is a growing trend for engineering education to address issues of human development. Vesilind suggests that, historically, engineers have been employed as "hired guns, doing the bidding of both political rulers and wealthy corporations[21]. However, he says, there is a new kind of engineering

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emerging, one “rooted in the greater ideas and aspirations of engineering as a service to all humanity.”[21] Robbins also predicts that we are at the beginning of an emerging field in engineering.[22] Second, there is a need to embed globalization within the engineering curriculum to provide students with the knowledge and skills to respond to globalization issues and to work in a global context. The importance of globalization of the engineering curriculum has been highlighted by various researchers. Some of these researchers suggest that showcasing engineering within a global context is necessary for global competitiveness, cultural inclusivity, and sustainable design.[23,24,25]

Vandersten closely links presenting engineering in a global context to the humanitarian engineering pedagogy.[26]

Humanitarian Engineering (HE)

According to, Humanitarian Engineering (HE) as a discipline was founded in 2003, when the William and Flora Hewlett Foundation funded the creation of a minor program at Colorado School of Mines (CSM).[27] Muñoz describes the new discipline as “a wave that’s passing through the world among young people that are bent on trying to improve the lives of humans on the planet in a sustainable way.”[28]

Though Munoz describes humanitarian engineering as a discipline and established it as a full program at the School of Mines, this paper showcases the integration of humanitarian engineering an existing engineering course/curriculum.[27] The argument is made that where having humanitarian engineering as a program may be challenging due to time and resource constraints, Colleges can integrate humanitarian engineering in already existing courses. This integration provides students the opportunities to be globally competitive, but more so to better appreciate cultural diversity which has a boomerang effect on creating an inclusive learning environment for female and underrepresented students in Engineering.

Burnham highlights that compared to other professions, Engineers seems to have immense power and responsibility and should therefore be afforded the opportunities to channel this desire for positive change around the world.[29] Engineering Education should therefore prepare students to make lasting positive impact in the lives of people globally.

Munoz also defines Humanitarian Engineers as Engineers who “try to balance technical excellence, economic feasibility, ethical maturity, and cultural sensitivity” through a set of specially designed technical, humanities, and social science classes, as well as a Design Experience.[30] This could arguably be said to really be the definition of an engineer, not just a humanitarian engineer.

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Munoz also went further and defined the Humanitarian Engineering Program by breaking down the definition as:

"Humanitarian: an artifact, process, system, or practice promoting present and future wellbeing for the direct benefit of underserved populations."[31]

"Engineering: designing and creating a component, subsystem, or system under physical, political, cultural, ethical, legal, environmental, and economic constraints."[31]

"Humanitarian engineering: design under constraints to directly improve the wellbeing of underserved populations."[31]

HE seeks to augment technical engineering expertise with understanding of the social, political, and economic realities that define the systems in which engineers live, work, and for which they design solutions.[29] HE looks to address, in a comprehensive way, the needs of students, faculty, industry, the global community, and governmental as well as non- governmental organizations, to work toward solutions to the basic problems plaguing the human experience on earth.[32]

Humanitarian Engineering is quite popular with many engineering students, as there is a need for the students to see that their future work or career would contribute to making a positive impact in the world. In many US universities, there is an increase in student interest in service learning, community engagement, and global issues, with undergraduate and graduate programs developing to support this interest.[33] Claes Helgesson notes that, "many engineering students and professional engineers are frustrated at being tied up with solving problems connected to people in the wealthy part of the world."[34] This new movement towards active social responsibility in engineering has a desire to ensure that products, systems and processes designed by engineers are not just meeting functional standards but are also meeting societal standards.

HE similar to context based learning pedagogy helps the student contextualize their work, see the direct value and applications, create accurate mental models and as such become intrinsically motivated to pursue their engineering education. This popularity of HE is even more evident amongst female and underrepresented students.

Various researches suggest that one of the most important plus of Humanitarian Engineering is that it can attract and engage a more diverse pool of individuals.[35] There is a growing understanding that, for women and for students from some underrepresented groups, a major factor in career choice has to do with making a difference.[35] "This has not been a widespread image—engineers as members of one of the 'caring professions.' But it's an image that we can build, both for our students and for the community as a whole."[36]

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A number of Colleges with HE programs are beginning to see greater diversity in their engineering cohort of students. Purdue and Colorado School of Mines have reported that over twice the percentage of women are interested in HE than in the average engineering department.[37] This is encouraging news given the fact that "the U.S., as a nation, has made no progress in diversifying engineering in some key dimensions."[38]

Through showcasing the ideas of HE, engineering schools can attract more minorities, such as women and non-technically oriented students, pushing diversity in engineering to new levels, and widening the range of perspectives needed to solve problems. The concepts at the core of the Humanitarian Engineering (HE) movement are not utopian fantasies, but rather a realistic analysis of where engineering has been, where it is now, where it is heading, and what engineering students need to learn today in order to be prepared for the future.[38]

Ohlone College Engineering for Female and Underrepresented Students (EFUS) Project through the Introduction to Engineering Course

Research has shown that the need to nurture in female students is one of the reasons why they pursue careers in healthcare and the arts. Hence the EFUS project aims to provide the opportunity for female students to 'nurture' through engineering and as such engage them in seeing that engineering provides a lot of opportunities to create solutions that 'nurture'. Engineering for Humanitarian needs will likewise create the feeling of being valuable and relevant in solving problems around the world, as gain research has shown that being valuable is important for underrepresented students to stay engaged in a course/career.

The EFUS project was first implemented in the Spring Semester of 2014. The IEEE-CPMT/SCV funded the project with $2500, donated to the Ohlone College Foundation. The project was embedded into the Introduction to Engineering Course, which has the flexibility and scope to support the EFUS Project. Students were very excited and motivated just to hear that their course/project is being supported by the IEEE-CPMT/SCV, it gave them a sense of belonging to a larger community of Engineers and also made them feel valued. This in no small way was instrumental to the intrinsic motivation evidenced by all the students on the course while facing design and team work challenges during their projects.

The project gave the students a taste real life Engineering as they went through the whole Engineering Design cycle and Problem Solving Sequence on their respective projects. The female and underrepresented students in the class where motivated to take on leadership roles in their teams and contributed to identifying humanitarian needs in the world and formulating probable solutions. Furthermore the female and underrepresented students felt valued and had a sense of purpose as they saw how they could change the world positively and engage in a good cause through engineering (this was particularly true for the female students).

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Many of the students from underrepresented ethnic groups felt valued as they identified and discussed humanitarian needs that they or a family member or friend was experiencing/had experienced. They also highlighted to their team mates the appropriate technologies that could be used to solve those humanitarian problems. Feedback from the students concerning the EFUS Project was very positive. Here are some quick statistics from the students' feedback.

- 100% of the students felt that the EFUS project had motivated them to stay on course with their Engineering Education and Careers.
- 100% of the Female students mentioned that through the Project they saw how they could change the world positively through Engineering.
- 100% of students who were undecided about Engineering as a career (at the beginning of the semester), decided to commit themselves to an Engineering Education (80% of the female students decided to take summer math classes to speed up their Engineering Education).

The students also presented their Projects at the Ohlone STEM day on May 9, 2014 to 60 Middle School Students. This had a domino effect as many of the middle school students were very interested in the projects and wanted to design and build the sort of prototypes they saw. The EFUS Project students felt a sense a fulfillment as they were also engaged in the process of encouraging the next generation of Engineers, through Service Learning. The EFUS project also featured the June edition of the Tri-City Newspaper (http://www.tricityvoice.com/displayPages.php?issue=2014-06-24&page=5)

Implementing the RET UC Berkeley Experience in the Introduction Engineering Course at Ohlone College

The RET experience was an invaluable experience that supported the pedagogical methodologies of humanitarian Engineering and Context Based Learning. Community College Faculty engaged in research on Sustainable Manufacturing which was easily embedded in the Introduction to Engineering Course as a topic under Engineering Ethics and Engineering Design. Students had to include different aspects of sustainability in their Capstone Projects which was underlined by humanitarian engineering theme. The research experience at UC Berkeley provided Faculty with an in depth understanding of global sustainability issues which faculty discussed in the class room and provided students with a better understanding of these issues.

Again the retention of female and underrepresented students is significant as many have made a commitment to engineering as a career. Feedback from some students were;

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"The Humanitarian Engineering Project really made me see the difference I can make as an Engineer;"

"I now see that Engineering is also about caring for the world- which I really want to be part of."

"My opinions as a female student were valued as we had to really understand the social injustice that people face- somehow my team of male students valued my contribution and I took leadership role".

In conclusion this paper highlights the role that humanitarian engineering and context based learning has in retaining/increasing the number of female and underrepresented students and shows how HE can be effectively incorporated in the Engineering Curriculum via the Introduction to Engineering Course. This paper also highlights the importance of Programs like the UC Berkeley RET program for Community College Faculty in propagating HE and CBL.

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Design of a Spatial Visualization App for Increased Student Engagement

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Abstract

Hand sketching of isometrics and orthographic projections is an important skill for concept generation and team brainstorming. In addition, hand sketching skills increase spatial visualization abilities, which have been correlated with increased GPAs in math and science. In an effort to teach freehand hand sketching and spatial visualization skills in an engaging and cost effective manner, two applications that use iPad touchscreen technology have been developed. The Spatial Visualization Trainer™ (SVT), targeting high school and undergraduate students, and Spatial Kids™, targeting K-8 students, allow users to learn spatial visualization skills independently. A unique feature of these applications is that hand sketches are graded automatically. Once a student submits a sketch, they receive an indication if their work is correct (within a tolerance threshold). When students have an error in their sketching solution, they are given the option to redo the sketch or take a peek at the solution. To evaluate the effectiveness of the App, a course was taught in Spring 2014. 54 students completed the course using the SVT software on iPads during class with a teacher present, and took a pre- and post- assessment test to gauge improvement. Of the 13 students who began the class with a low pre-test score (<70%), one subgroup increased their post-test score by 43% while the other sub-group had virtually no improvement and actually had an average score decrease of -4%. The primary difference between these two groups was that the students who did not see improvement peeked at the solution with minimal effort to challenge themselves and try on their own. Accordingly, the App has been redesigned with the focus of increasing student engagement and student persistence. This paper introduces four main modifications that were made: 1) the development of assignments that start simple and get more complex, 2) an intermediate option to receive a hint (animation) before peeking at the solutions, 3) a point system (stars) to encourage students to try without taking hints or peeking, and 4) the use of a few assessment questions at the end of each lesson where the hint and peek options are disabled. This paper describes the SVT™ and Spatial Kids™ applications, the enhancements to the feedback provided to the students in order to promote engagement, and future directions.

Introduction

Spatial visualization is the mental representation and manipulation of 2D and 3D shapes. Skills in spatial visualization have been correlated to high GPAs in math, engineering, computer programming, and science. Spatial visualization concepts are seen in geometry standards in K-12, but they are not emphasized in most K-12 and undergraduate curriculums. It has been shown that a single course that teaches spatial visualization skills increases GPA and graduation rates in Science, Technology, Engineering, and Math (STEM) fields[1]. Also, improving spatial

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visualization skills has been identified as a priority for increasing the percentage of women in STEM fields[2], as well as other underrepresented minorities.

Past spatial visualization courses utilized a combination of multiple-choice questions and freehand sketching assignments[1]. While multiple-choice questions can be easily integrated into online learning technology, freehand sketching of isometric and orthographic projections are quite different. Traditionally students sketch on paper, which are manually graded by the instructors, who then provide feedback the next time the students attend class[3]. While it is possible to teach the multiple-choice questions without the sketching assignment, studies have shown that students see higher learning gains when sketching exercises are included. Moreover, sketching is an important part of technical communication, teamwork, and creativity[4].

To enable spatial visualization instruction incorporating hand sketching to reach a broad distribution of students in an engaging, cost effective, and easy to teach manner, two applications that use iPad touchscreen technology have been developed. The Spatial Visualization Trainer™ (SVT), targeting high school and undergraduate students, and Spatial Kids™, targeting K-8 students, allow users to learn spatial visualization skills through hand sketching with immediate feedback being provided by an automatic grading algorithm that includes the ability to receive guidance when requested.

With online courses and tools becoming more widespread in K-12 and undergraduate education, the spatial visualization Apps have been recently modified so they can be used autonomously without the need for an instructor, in a classroom setting, or in a hybrid environment. Four main modifications were made: 1) the development of assignments that start simple and get more complex, 2) an intermediate option to receive a hint (animation) before peeking at the solutions, 3) a point system (stars) to encourage students to try without getting hints or peeking, and 4) the use of a few test questions at the end of each lesson where the hint and peek options are disabled to assess student learning. In addition to describing key features of the SVT™ and Spatial Kids™ applications (specifically the grading algorithm), this paper summarizes recent enhancements to improve the feedback provided to students in support of self-guided learning.

Spatial Visualization Training Apps

Previous teaching applications used multiple-choice problems to teach spatial visualization concepts. While multiple-choice problems are efficient for computerized grading, there are disadvantages to using multiple-choice problems to teach spatial visualization. In multiple-choice questions with complicated 3D figures, students may use the process of elimination to narrow down the possible answers without actually visualizing the object. In addition to this, a student who is incapable of answering a question may answer it correctly by guessing.

To address the shortcomings of using multiple choice questions, the SVT™ and Spatial Kids™ Apps create a platform for students to perform freehand sketching assignments. Students are required to sketch their answers. This makes it difficult for students to guess and move on to the next assignment without learning to visualize the 2D and 3D objects and answer the questions correctly.

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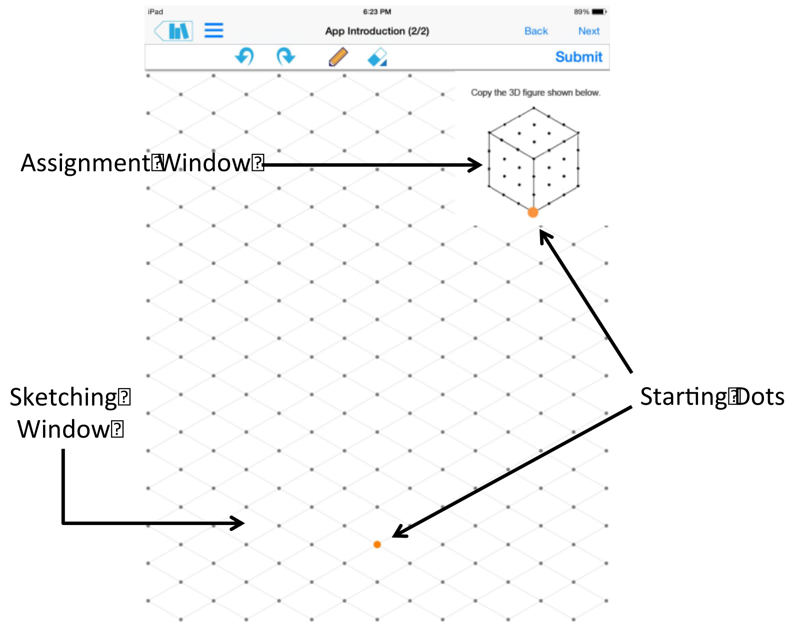

Figure 1: Assignment and sketching windows

Both Apps provide a grid in a small assignment window and a corresponding grid on a larger sketching window. The assignment and sketching windows have a designated starting dot and the user must draw their sketches such that the starting dots and the grid layouts match between the assignment and sketching window. Both App interfaces are very simple with a single color pen tool and an eraser. Figure 1 shows the assignment and sketching windows for a simple exercise of drawing a cube in the SVT™ App.

One of the key features of both Apps is the automated grading algorithm that provides immediate feedback to the user ultimately guiding them through the assignment solutions, and relieves the teacher from monotonous grading. This enables the Apps to be completed self-paced with minimal instructor supervision. Since the sketching assignments have a designated starting dot, there is a unique solution relative to the grid for each assignment. The grading algorithm determines if a user's sketch submission is the proper solution for the assignment within a designated tolerance[3]. Details of the algorithm will be published in a future publication. Once the user completes their sketch they press the "submit" button to grade their work. If the sketch is correct, a "good job" message is displayed to the user who moves on to the next assignment. However, if an error is detected, the user has the option to try again or peek at the solution. With a peek, the user sees the solution temporarily, but the solution disappears when the user continues sketching. Each time a user submits a sketch, a file is sent to a server that includes a copy of the sketch, how many attempts were made, and if peeks occurred. The server that stores student work and scores is password protected and is accessible to only the teacher and researchers. Figure 2 shows an example of the automatic grading feature for an incorrect sketch in both the SVT™ and Spatial Kids™ Apps. Green lines represent lines drawn correctly, solid red lines represent lines drawn incorrectly, and dashed red lines represent missing lines that the student did not draw.

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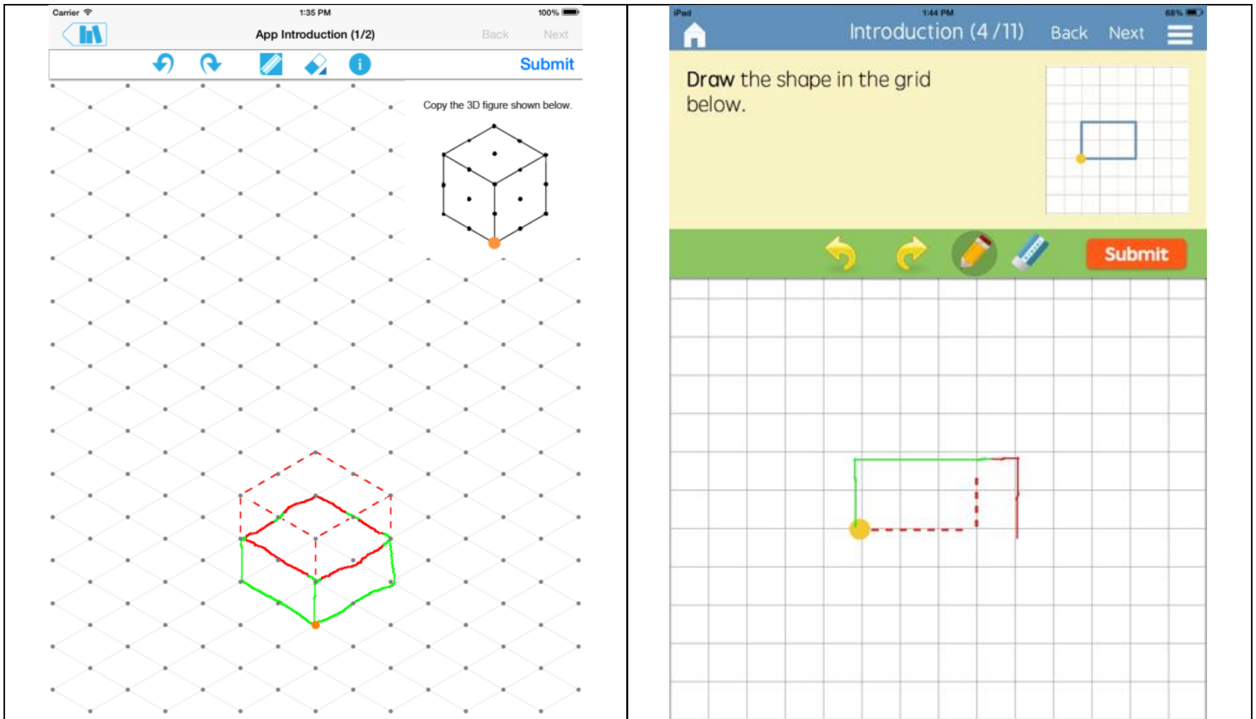

a) SVT App | b) Spatial Kids App

Figure 2: Automated Grading Feedback

Trial Spatial Visualization Course Using SVT App

A spatial visualization course was offered in spring 2014 as a 1-unit pass/no pass course. On the first and last day of the course the Purdue Spatial Visualization Test: Rotations (PSVT:R)[5] was administered and the pre- and post-test scores were used as an indicator of student learning. The class was split into sections of up to 20 students each. Each section met once a week for a three hour time period. They started with a spatial visualization brain-teaser, were given a mini-lecture on the topic of the day, reviewed tutorial material using the Developing Spatial Thinking[6] software, a web-based software package that was developed in the 1990's containing animations of how to visualize spatial visualization concepts, and finally worked on sketching and multiple choice exercises via the iPad SVT™ App.

Data was recorded every time a student submitted an answer for a multiple-choice or sketching assignment. In addition, for each sketching assignment, an image showing the submitted sketch was recorded, as well as whether the student chose to use the peek option and what attempt number the submission correlated to. These detailed data were analyzed for the 52 students who took the pre- and post-test. The students were categorized into three groups based upon their pre-test scores: a high group with scores over 90% (n=22), a mid group with scores between 70 and 90% (n=17), and a low group with scores below 70% (n=13).

The initial hurdle was to determine if the material was engaging so that users actually completed the assignments. In this regards, this trial was successful, with 93% of 2nd week enrollment completing the 10-week elective course, and 93% recommending the course[3]. Student comments

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indicate that they enjoyed using the iPad software and were able to adjust to sketching using the iPads.

The automatic grading algorithm determined if a sketch was correct and collected extensive data that provided insights relevant for both teaching spatial visualization and evaluating learning approaches in general. Among the group of students who came into the course with low spatial visualization skills, some of the students learned a large amount with performance gains on the post-test of 43%. However, other students had virtually no increase in their post-test scores. The largest measured difference between these two sub-groups occurred when students were confronted with a mistake in their initial sketch attempt. Those students who did not improve their post-test scores chose to peak on all but 7% of these instances and often their initial effort was minimal with the peek being used as a crutch to quickly gain access to the solution. In contrast, the students in this sub-group who increased their scores on the post-test more often than not resisted peeking and tried to solve the problem on their own. This difference in peeking between these two subgroups was 74%, indicating that both the learning approach and outcomes was bimodal. The increased performance correlated most strongly with perseverance and effective learning (indicated by avoiding peeking) than with other metrics such as the percentage of questions answered correctly[3].

The trial course indicated that students who revert to peeking too easily do to not learn as much. To encourage active learning and perseverance, but still provide the peek option so students can work independently, several new features have been integrated into the Apps such as starting with simple assignments that become more complex, providing a hint as an intermediate option before a peek, providing a point system (stars) to encourage students to attempt the sketch without peeking, and including Assessment Questions at the end of each lesson where the hint/peek options are disabled. These features have been implemented initially in the Spatial Kids™ App and are described in detail in the following sections.

Self-Guided Learning

Simple Assignments that Become More Complex

To build student confidence and guide students to a stronger understanding of spatial visualization skills, the content for each chapter in Spatial Kids™ was modified to start with simple assignments that increase in complexity as the students master the skills. An example of this approach is demonstrated using the concept of flat patterns, which are 2D patterns that can be folded up to make a 3D object.

Most assignments for this spatial visualization concept are multiple-choice based, making it easy to guess the solution without really understanding the concept. Therefore, the development of free response questions for this concept is desirable. The assignments in the Spatial Kids™ App start very easy, to demonstrate how the questions will be structured and encourage students to continue learning. As the students successfully complete each assignment, they progressively get more challenging, building on the skills and concepts learned through earlier assignments.

Figure 3a provides an example of a multiple-choice flat pattern question in the SVT™ App. The student is tasked to designate which patterned side is missing in the flat pattern such that it

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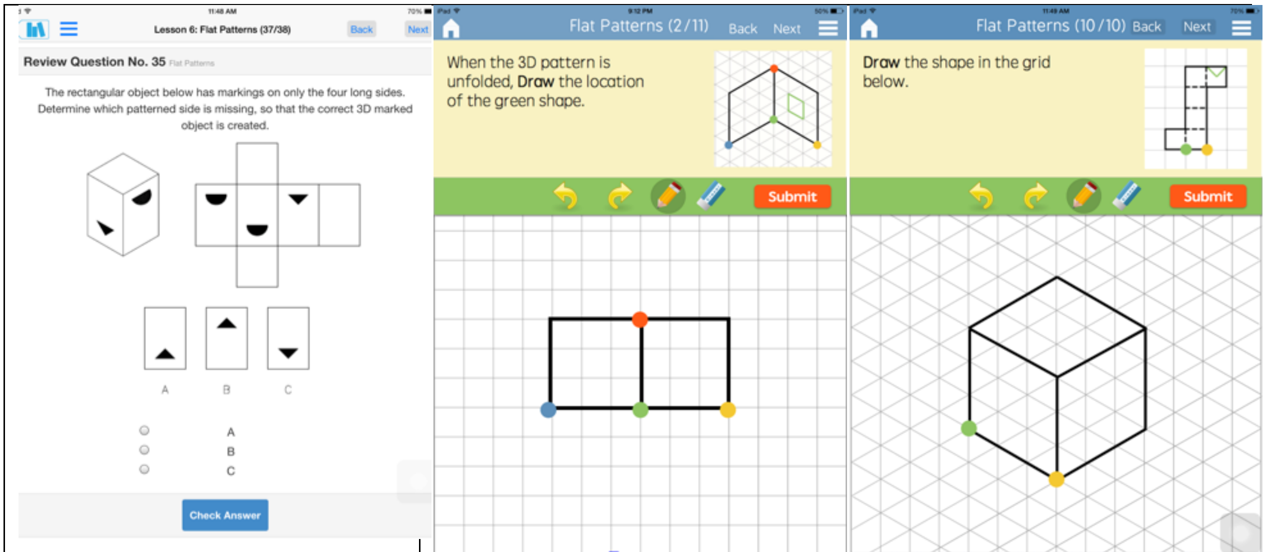
produces the 3D object in the figure. Students can use the process of elimination to guess the correct answer but may not really learn to visualize how the flat pattern folds up into the 3D shape. In comparison, Figures 3b and 3c show free response questions from Spatial Kids™ that start easy by having students unfold a 3D shape into the flat pattern and draw the location of the green shape (Figure 3b). They get more challenging (Figure 3c) where the student has to mentally visualize the flat pattern folding into the cube and draw the face and orientation that the green shape from the flat pattern ends up on in the 3D object.



a)	b)	c)

Figure 3: Flat Pattern Examples: a) Multiple choice from SVT™, b) Easy free response from Spatial Kids™, and c) More Challenging free response from Spatial Kids™

Assignments also increase in complexity as students progress through the various chapters. For example, the Tetromino chapter in Spatial Kids™, which is based on the popular game Tetris™, builds on concepts learned from the introduction and 2D rotation chapters of the App. Students not only find the Tetris™ style assignments appealing, but are able to apply the concepts previously learned and gain confidence in their spatial reasoning skills.

Intermediate Feedback Option (Hint)

To improve the user experience and encourage students to not peek as much, a third option was added when a user answers a problem incorrectly. In addition to retrying the problem or peeking at the solution, a user can get a hint (animation of an example demonstrating the concept) (Figure 4a). The animation is a video clip often showing the solution being drawn, and can be played as many times as the user wants (Figure 4b).

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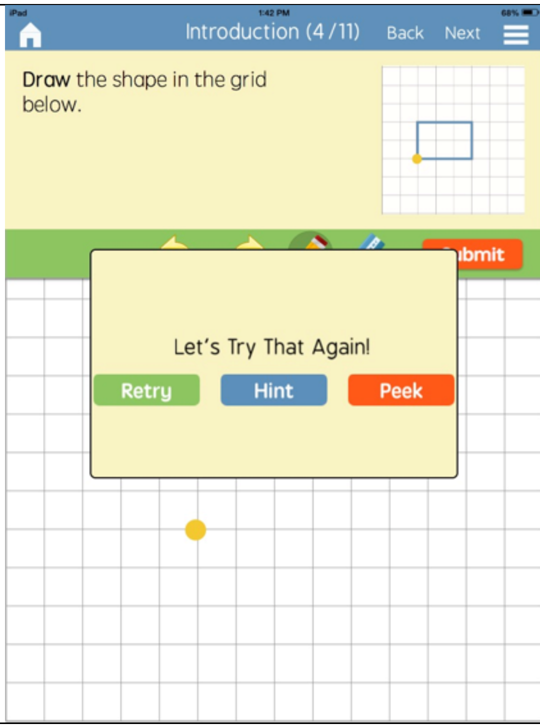	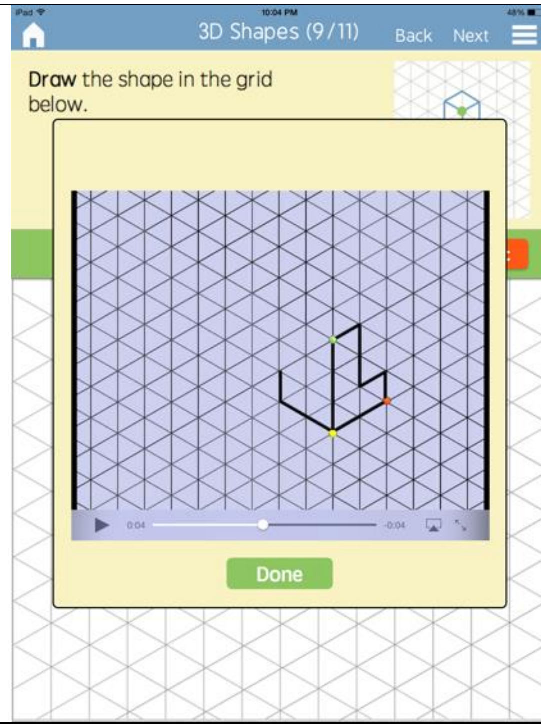
a) Third option (Hint) provided when incorrect sketch is submitted.	b) Example Hint (animation) showing sketching of solution that can be replayed.

Figure 4. Hint Feedback Feature in Spatial Kids®

Incentive Program (Star System)

Another feature recently added to Spatial Kids™ is an incentive program or star system to dissuade students from peeking too much before trying the assignments to the best of their ability. Students are allowed to retry an assignment as many times as they want and as long as they solve the assignment without taking a hint or a peek they get three stars (no star penalty). The App does not want to discourage students from taking a hint when they really need assistance, so if a student uses the hint option and then solves the problem correctly they get two stars (a 1 star penalty). Finally, students who peek at the solution, which shows their graded sketch instantly and provides insight as to what is wrong with their solution, get one star (a two star penalty). Figure 5 shows the three different possibilities within the star incentive system.

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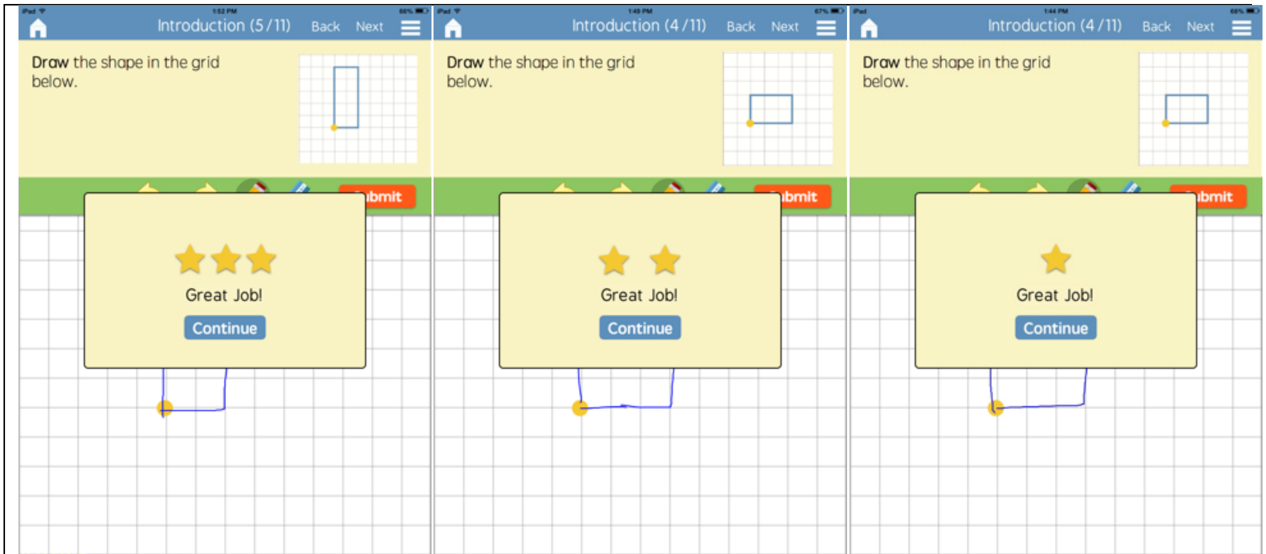

a) 3 stars gained for no peeking	b) 2 stars gained if use the Hint	c) 1 star gained if use the Peak

Figure 5: Incentive Program (Star System) in Spatial Kids™

Assessment Questions

In earlier versions of the Apps, students were allowed to peek at the solution for any sketching assignment if they did not succeed on their first try. However, it was observed that some students were peeking after only minimal effort in solving the problem on their own. Accordingly, the last two sketching assignments in each lesson in the current versions of the Apps are designated as "Assessment Assignments" and the hint and peek options are disabled for these assignments. Essentially, the Apps are programmed such that the hint and peek are only an available option when the first attempt is incorrect and the assignment is not one of the Assessment Assignments. If students are made aware that there are questions at the end of each lesson where the hint and peek options are unavailable, they will become more attentive during the earlier assignments. In order to fully complete a chapter and advance to new concepts, students are required to complete the Assessment Assignments.

Conclusions and Future Work

The unique aspect of the SVT™ and Spatial Kids™ Apps described in this paper is the electronic method for teaching freehand sketching, which is an important component of spatial visualization training as well as essential for strong technical communication and creativity. The use of a touchscreen enables automatic grading of the sketches and the ability to provide guidance when requested. The eventual use of the Apps could be in a classroom setting, used for independent learning, or part of a hybrid environment.

Developing an effective eLearning tool with functionality that supports spatial visualization training is challenging. Introducing certain features may lead to unwanted behavior such as the peek function, which in a pilot study of undergraduate students led to results demonstrating that students who peeked regularly without giving their best attempt on the sketching assignments ultimately resulted in lower learning gains. To overcome some of these observed behaviors, while also creating a mechanism to support independent learning, four main features have been

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added first to the Spatial Kids™ App: 1) the development of assignments that start simple and get more complex, 2) an intermediate option to receive a hint (animation) before peeking at the solutions, 3) a point system (stars) to encourage students to try without getting hints or peek, and 4) the use of a few test questions at the end of each lesson where the hint and peek options are disabled to assess student learning.

These innovations will be incorporated in the SVT™ App and several pilot studies will be conducted (one using the SVT™ App with undergraduate students and several using the Spatial Kids® App with K-6 students around San Diego county).

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A Proposal for Workshop

&

Abstracts for Posters

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Workshop: Using Inquiry-Based Learning Activities in Engineering Courses to Promote Conceptual Understanding

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Have you wondered how to make your students curious about your content, how to get them discussing the important concepts in your class? We have found that presenting them with a physical situation and having them predict the outcome – especially when they predict that outcome incorrectly – can create a engaging learning environment. Our work centers on Inquiry-Based Learning Activities (IBLA), which follow the general cycle shown in Figure 1.

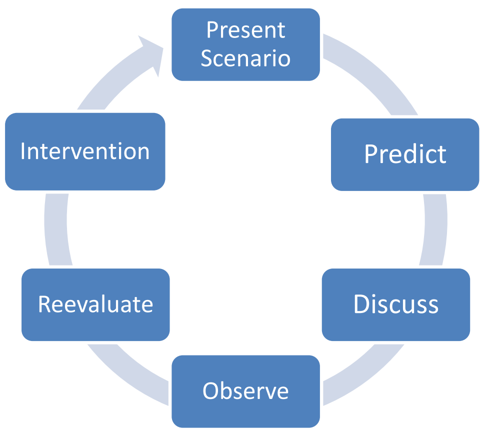

Figure 1. Learning cycle for IBLAs.

We first present students with a physical scenario. For example, a solid cylinder and a pipe, each with the same outer radius and mass, are placed at the top of a ramp. Which will reach the bottom first (or will they reach it at the same time)? Students must first submit an individual prediction, which forces them to confront their own conceptual understanding. After this prediction, students discuss the scenario with their teammates (promoting collaborative learning). Following this, the students conduct the experiment, allowing the physical world to be the authority instead of the instructor. After team discussion of the results, the instructor may intervene and provide some guidance or explanation, or may simply present an additional scenario to help students investigate the relevant concepts. An IBLA team worksheet is used to help guide student discussion and to record their explanations. At the end of the multi-cycle IBLA, we typically have a follow-on discussion and/or homework problems to reinforce the relevant engineering principles.

Although the exact definition of inquiry-based instruction varies somewhat between different investigators, we will use the defining features offered by Laws et al.[1] and highlighted by Prince and Vigeant[2] (see Table 1).

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Table 1. Elements of Inquiry-Based Learning Activities.

(a) Use peer instruction and collaborative work
(b) Use activity-based guided-inquiry curricular materials
(c) Use a learning cycle beginning with predictions
(d) Emphasize conceptual understanding
(e) Let the physical world be the authority
(f) Evaluate student understanding
(g) Make appropriate use of technology
(h) Begin with the specific and move to the general

Our team has developed and tested five different IBLAs for use in introductory dynamics[3]. The IBLA name and targeted concepts are provided in Table 2.

Table 2. Targeted concepts for IBLAs.

	Targeted Concepts
Pulley IBLA	System mass, net force, and acceleration (particles)
Pendulum IBLA	Linear momentum, work-energy, impact (particles)
Spool IBLA	Force, moments, linear and angular acceleration, rolling friction (rigid bodies)
Rolling Cylinders IBLA	Mass distribution, angular acceleration, translational and rotational kinetic energy, potential energy (rigid body)
Gyroscope IBLA	Angular momentum, applied moment, change in angular momentum direction, gyroscopic motion (rigid body)

As shown in Figure 2, the Pulley IBLA consists of two Atwood machines placed side by side. The masses on each side of the pulley are varied for each case (see Figure 3), and students are asked to predict what will happen when the system is released from rest. Although a very simple application of Newton's second law, students still struggle with overall system mass, identifying and applying net force, and transferring their knowledge to a final case involving an applied load, Case (d). Our group has conducted several think-aloud protocols to further help us improve the IBLA and to investigate student conceptual

Figure 2. The Pulley IBLA.

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understanding[4].

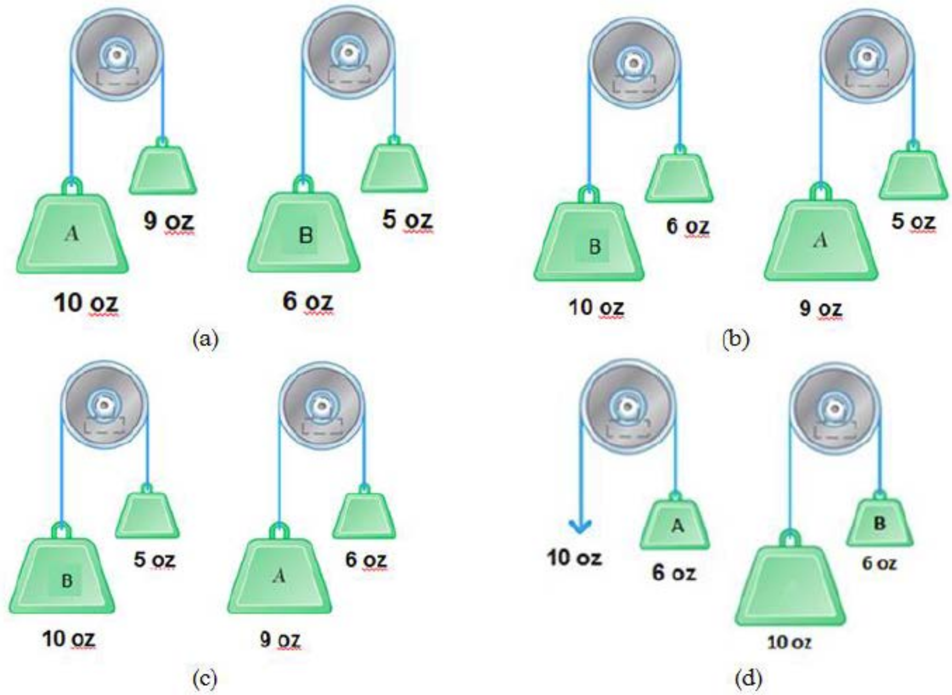

Figure 3. Four cases of the Pulley IBLA.

During the workshop, participants will conduct an IBLA, acting as if they were the student. After discussing the basic principles of developing and implementing IBLAs, attendees will be given the opportunity to work on developing an IBLA for their own class. At the end of the workshop, participants will present their new IBLAs to the group for feedback.

Inquiry-Based Learning Activities have been very successful in the physics educational community[5], and we think they provide great promise for many engineering topics as well. By first developing conceptual understanding, students can build a framework for attacking more complex problems later in their coursework. The hands-on activities provide a memorable learning experience for students, promote a collaborative learning environment, and should be incorporated into a wide variety of engineering classrooms.

Acknowledgments
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An Innovative Design of a Hotel Reservation System

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This study designs and develops an Online Hotel Reservation System (OHRS) using modern design principles. The system automates online room reservation process of hotels by providing an exceedingly flexible process which is easily adaptable to any type of hotel such as Suite hotels, Inns, Resort hotels, Motels or Boutique hotels etc. Reward points are added for all the registered users for every check-in and special rates are applied based on reward points.
This system provides a cloud service from a leading cloud service provider such as amazon web services and gives the complete control of a system to the hotel managers. It doesn't use any third party booking operators such as Priceline or Expedia for online room reservations but gives the direct services to multiple hotels in a cloud.

OHRS provides rich and simple user interface and many customization features for the hotel management such as customizing the themes of a system, adding picture gallery, writing custom messages etc. In addition, it provides dynamic pricing feature for the hotel management which adjusts the price of a hotel based on certain criteria. Some other features like Internationalization, Searching, and Maps (used to find the directions of hotel property) and Inventory management of customers will add the value to the system.

OHRS solves the real time booking problems by avoiding the third party services and users can avoid put themselves into the risk by sharing personal/bank details with the other booking sites. System provides high security to the customer profiles and their credit card information by applying encryption techniques and other security integration to all the sensitive data in the website. Hotels can gain more profits with their own hotel software by avoiding the commission charges to other booking sites. The simple and intuitive Mobile user interface will attract and enable visitors to book hotel rooms instantly. Hotels can reduce reservation system running costs further by using infrastructure in a cloud.

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Hybrid Solar Updraft Tower Compost Waste Heat Solar Energy Co-Generation Facility Sponsored Industrial Project

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A solar updraft tower is a renewable energy structure that harvests energy from the sun and creates high velocity wind speed in its collector to run turbines. The stakeholders for the development of this renewable energy technology include the community, nation and global inhabitants. A compost pile contains microbes that digest organic material and break it down into smaller parts. When they do this, they produce heat as a byproduct. The heat production depends on the size of the compost pile, its moisture content, aeration, and C/N ratio. A well composted mass often reaches temperatures of 66 to 82 DEG C, which falls within the range of low-grade waste heat. Compost managers strive to keep the compost below about 65 DEG C since hotter temperatures cause the beneficial microbes to die off. Aeration is typically used to manage the compost temperature. The energy liberated by aeration can be fed into the convective stream of the solar updraft tower. This paper extends this concept as a viable renewable energy source by extending the use of the solar chimney which uses low-grade waste heat from compost in conjunction with solar energy generated from a photovoltaic array in order to set up the convective flow in the solar updraft tower which uses turbines to harness the energy and convert the flow work into electricity. The convective air-flow in the updraft tower propels a novel concept of turbine arrays fixed in the tower of the solar tower. Thermodynamic and turbo-machinery analysis on this novel turbine concept is presented in this paper. In this paper, the mathematical model of the system is established based on thermodynamics and elementary fluid mechanics and heat transfer theory. Various parameters including the heat source temperature, the ambient air temperature and area of heat transfer are examined to evaluate their effects on the system performance such as velocity of updraft, mass flow rate of air, tons of compost per day, compost moisture content, aeration, power output and energy conversion efficiency. Initial findings indicate that the velocity in the updraft tower is directly proportional to the available heat transfer area, the solar panel square footage, and the amount of heat taken from the compost. These trade study results are presented parametrically in the paper. Preliminary plans for a proto-type solar updraft tower utilizing compost waste heat and solar energy are also outlined in this paper. The paper will also outline the use of Systems Engineering to coordinate the logistics of feeding the compost waste on a conveyor belt from the trash trucks to the compost waste / solar chimney infrastructure (28 acres, 24 chambers, 8000 tons of waste per day or more). This research is sponsored by COMPO Energy, Inc. which holds the U.S/ Green Energy Patent Number 7,956,487 on the compost technology concept discussed herein.

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Computational Simulation of Local Blood Flow in The Human Carotid Artery

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Local blood flow in three healthy carotid artery geometries was simulated using a computational fluid dynamics (CFD) tool, COMSOL Multiphysics, to compare local hemodynamics among the three arterial models. The carotid artery consists of common carotid artery (CCA), external carotid artery (ECA), and internal carotid artery (ICA). The morphology of the human carotid artery bifurcation has been reported as one of the critical factors for the development of atherosclerosis at the bifurcation. Numerical analysis of various local hemodynamic conditions in the human carotid bifurcation might provide us better understanding of the underlying causes of carotid artery stenosis.

The carotid artery models were created in SolidWorks and then imported to COMSOL for this study. Tetrahedral mesh structure of the model was constructed in COMSOL with the element dimensions in between a minimum of 0.214 mm and maximum of 0.716 mm. Time dependent single phase laminar flow condition was applied using Navier-Stokes equation. The density and dynamic viscosity of working fluid were set at 1060 kg/m3 and 3.2×10-3 Pa·s, respectively. The boundary conditions of corresponding flow and pressure waveforms were applied for each model. The results showed that three carotid bifurcation models had a similar average velocity of 0.27 m/s at CCA during the peak systole, and did not show any significant difference in pressure at CCA. However, downstream flow in two daughter branches (ICA and ECA) showed a remarkable difference among the three models. When the flow separation ratio of ICA:ECA was calculated, Model#1 showed the ratio of 80:20 between ICA and ECA, however, Model#2 and #3 showed the ratios of 70:30 and 65:35, respectively. It seems that the arterial geometry with associated pressure gradients might cause the flow rate variations in two daughter branches. This study was a preliminary investigation on few carotid bifurcation geometries with associated blood flow conditions. Extensive study of blood flow simulation with various carotid artery geometries should be considered for the better understanding of hemodynamics in the carotid bifurcation.

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Visualizing and Measuring Complexity of Introductory Physics Problems Through Graph Diagrams

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At the heart of engineering is the use of observations, calculations, and models to solve problems. Difficulty of introductory problems ranges from straightforward to complex and multistep. In the former case, only a single equation or principle need be applied, while in the latter case multiple equations are required, often in unfamiliar context (Finney, 2003). While many agree that multistep and complex problems are difficult and stressful to solve (Lin et al. 2013; Yerumalshi et al., 2010), no specific definition of problem complexity has been accepted. Firstly, one could relate the complexity of a problem to the number of steps required for its solution. Gire and Rebello (2010) determined problem complexity in terms of an Exposition-Complication-Resolution framework, based on the number of calculations required to bridge the quantities given in a problem with its goal. Complexity was ultimately scored by independent raters. Secondly, complexity depends on the solver's level of expertise or prior exposure to similar problems, which once again is determined subjectively (e.g., through questionnaires or ratings).

We implement an approach that automatically combines both of these aspects for determining complexity of introductory physics problem. This approach assigns a problem's variables to one of three categories: "given" if the value of the quantity is given to the reader, "wanted" if it is the quantity that needs to be solved, and "hidden" if it is neither given nor wanted. Relationships between these variables are shown through network visualizations. These graphs are visualized in Javascript using the D3.js framework. Using a relational database, we first link the quantities based on their category. Second, we link these quantities (nodes) based on their co-occurrence in equations (edges). The number of steps to bridge any set of given quantities to wanted ones can be clearly visualized in a force graph diagram. Steps from a given node to a wanted node naturally correspond to the number of steps required to solve a problem, with hidden quantities corresponding to intermediate nodes in the graph. Additionally, we adjust physical distance between nodes to reflect problem exposure. Based on problems in a given set, the more often two quantities occur in any category the shorter their edge is made. Thus, problem exposure can be implemented as a shortening of node distance based on how many times, and in which categories, those nodes appear within a given set of problems. Such graphs can be used to visualize the number of steps required to solve a problem, and proximity of nodes can be interpreted as a cognitive "distance" between quantities. Metrics are presented that compliment this visualization approach.

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Vacc-In-ICE: Zoelite Adsorption Refrigerator

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Our team's objective was to construct an engineering innovation to help the people of Earth for any humanitarian needs while following the engineering design loop stages. After brainstorming ideas of humanitarian issues, we came up with an issue we wished to provide a solution for: the issue of sustainable energy to keep vaccinations refrigerated in areas around the world that do not regularly get electricity. With a budget of $100 during a 6 week time frame, our team has accomplish creating an off-the-grid adsorption refrigerator.

After intense researching, we found a cheap, environmental-friendly refrigeration system using zeolite, a natural mineral, and water as the adsorption-evaporator components. By lowering the pressure in the evaporator vessel using a vacuum pump powered by a solar panel, the water inside the vessel begins to pass the triple point of water to where water begins to boil at temperatures close to 0°C. During this process the high energy water molecules transition from liquid to gas, leaving only the low energy water molecules behind to freeze. The valve connecting the vacuum pump to the system is closed and the zeolite valve is open. This allows the water vapors that were boiled off to travel through the pipe and become adsorb by the zeolite creating a closed loop system keeping the ice frozen for a longer duration. After the zeolite is saturated with water molecules, the material is able to be reused by heating it to high temperatures to evaporate the water molecules, and the cycle of refrigeration starts again. While reviewing our results, it has shown great success, proving that this self-reliant system is simple to create and beneficial for people of rural areas without a reliable source of electricity. This refrigeration system is capable of preserving vaccines, as well as other items that need to be frozen.

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Outreach Program for High School Students in Cyber Security

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This program provides an intensive four-week long summer program where high school students come to the university campus for the full day each day. Students participated in either cryptography or general security focused projects and developed posters on their projects which were presented at the end of the program. The projects also involved an upper-division university student, a university faculty mentor, and a high school teacher. The program is modeled on an existing high school STEM outreach program at the university, which is popular with local high school students and teachers. The program has involved 36 high school students and 4 high school teachers over two years. Demographics for the students were diverse, with nearly equal gender participation and race/ethnicity reflecting the demographics of the region.

The goal of the program is to encourage high school students to pursue cyber security education in college, which will help prime the pipeline for an educated cyber security workforce. High school teachers are also involved so that they may take ideas back to their classrooms and further encourage their students to consider cyber security careers. The program is sponsored by an NSF SFS CyberCorp capacity-building grant, which provides stipends to all participants.

In order to gauge the impact of the program on the high school students' interests in college and cyber security, a pre-survey was administered at the start of the program and a post-survey was administered at the end of the program. The surveys contained matched questions that ask students to rate their excitement, interest, and preparedness on a Likert scale, as well as to indicate the college majors that they are considering. The pre-survey additionally contained background and demographic information. The post-survey had satisfaction questions plus questions asking the students to self-rate their change of interest on a Likert scale.

32 high school students and their parents consented to taking the surveys. Results for the matched questions show that students are very excited about the topic area at equal levels in both the pre- and post-surveys. This is despite students showing a lower rating in preparedness on the post-survey. This likely indicates that the program has made the high school students aware of what they didn't know, without dampening their enthusiasm. Students show a slight increase in interest in cyber security in general, but a slight decrease in interest in cryptography specifically. These results were also confirmed in the post-survey questions which asked the students to self-rate changes in interest. Students showed an increase in interest in general security, but only a slight increase in interest in cryptography. When looking at the results by gender of students, female students show a decrease in interest in cryptography on the matched questions while males show a slight increase in interest. Males were also more interested in engineering and technology majors than females. No other clear gender trends were observed. Open-ended questions did not give an indication of the reasons for the difference in responses.

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Partnering with Industry for Course Development: A Poster Session on a Funded Opportunity to Assess Student Success in the Market Place

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Academic partnering with industry is a paradigm shift that has taken many forms. The more recent discussions in this partnering paradigm shift is how the teaching itself is directly influenced by the partnership – course content and delivery method. Course content and delivery can better reflect the applied sciences and current issues of the market place through a partnership. Students can gain direct exposure and access to the current market place, without having to wait for an internship.

When considering the built environment and the building industry, the majority of new construction is for structures around three stories or less. Such buildings tend to favor timber and/or masonry as the economical choice. The consulting structural engineering profession has indicated a strong benefit for the student entering the market place who have had a more robust education that included an additional design courses.

In order to address the paradigm shift and the robust course offering issues, an engineering course in masonry design was developed with direct input from a professional industry association. Emphasis was placed on current industry practices – testing, quality of construction, and theory to code application. To address student success in the market place, a mechanism was put in place for market place assessment over a 5 year span.

This poster session will highlight the issue and solution (course development with partnership between academics and industry) and emphasize the opportunity for other universities to participate in market place assessment. In an effort to cast a "wide net" of assessment, additional universities are needed and their participation will include funding. Participation includes teaching one course a year in Applied Masonry Design for a five-year duration and to assess the student benefit in the market place. Participating universities will be provided complete coursework (Textbooks, Code Books, lecture notes, exams), course resources (materials for hands-on activities), travel reimbursement to attend an initial workshop, and funding for assessment. Participants would meet annually for a self-assessment workshop. An in-depth knowledge of masonry design is not a requirement to participate. The willingness to teach the course and assess the course impact on student success after graduation is a requirement.

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Hydroelectric Rice Incubator

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The objective of the initial engineering project was to find a way to follow the engineering design loop and create an idea to benefit humanity or provide for humanitarian needs. After being given a budget of $100 and being given six weeks to complete the project, we began brainstorming ideas. Ultimately, the idea we came up with was to address the loss in rural rice crops through a portable rice incubator.

We researched the topic and found that it was possible to power a rice incubator and allow for a quicker harvest with a hydroelectric generator powered by water draining from the rice paddies. Generally, rice is grown in very wet conditions, often submerged in approximately 50cm (20 in) of water. Once the rice is ready to be picked, the water is drained from the paddies using canals distributed throughout the field. If a hydroelectric generator was placed within these canals, power could be generated from the water drainage. This power could then be transferred to an accumulator to be stored for future use. When the rice is ready to be dried after harvest, farmers could quickly dry the rice within the incubator and distribute it to customers. Often times, crops can be lost after harvest due to the relatively primitive methods used to dry the rice. Farmers will often simply set the rice in their yard to air dry but in countries such as Laos, Thailand, Cambodia, and Vietnam, rainfall can ruin these crops before they properly dry. Using an incubator to speed the process would decrease the chances of crops being ruined and, due to enclosure, protect the crops if rainfall were to occur while they were drying

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Power Bucket

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The Power Bucket addresses the lack of renewable energy in developing communities throughout the world, specifically in regions characterized by heavy rainfall. Our team decided on using a small pressurized vessel to hold a small volume of water to be released in a controlled fashion through a nozzle aimed at a drive wheel coupled to a generator. Where possible the prototype was built using reclaimed materials and low cost, off the shelf components. In the end it turned out to be relatively simple and cost effective at around fifty dollars for all non salvaged parts, and only one complex fabricated part.

After some optimization the prototype was able to generate and maintain a useful voltage (>12v) for approximately 3 minutes. The duration was limited first by the small size of the containment vessel and second by the fairly small volume of the water source.

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Design and Implementation of an EMG Control System

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This project is the product of the collaboration between four community college students as part of the CIPAIR program. It aims to integrate electromyography (EMG) sensors into the wireless control system of a wheel-based robot utilizing Bluetooth. The implementation of this control system focuses primarily on an algorithm that converts the changes in electric potential across muscles into digital signals that will be interpreted as executable commands by the robot. The conversion of the digital signals is performed by a Texas Instruments LaunchPad board that hosts a TI MSP430F5529 USB microcontroller. The microcontroller is programmed using the Code Composer Studio v6 and C99 language. A second identical LaunchPad is part of robot itself and the data will be communicated wirelessly between them utilizing a TI Bluetooth booster pack. A secondary specification of the interpretation algorithm is consistency across many users, regardless of minor variations in EMG sensor placement and muscle characteristics. Further development of this project includes infrared sensor incorporation for automation purposes (e.g., collision evasion). The final outcome of this project is the development of an inexpensive platform of both hardware and software that can be ported to broader hands-free and handicap-friendly applications that require wireless control of devices.

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Modeling and Implementation of Brain-Inspired Neural Network for Edge Detection and Object Recognition

Rita Melgar, Carmen Yoc, Mou Sun, Anthony Nash

Canada College, Redwood City, CA

Artificial intelligence (AI) is a fast growing interdisciplinary field that, regardless of its vast achievements, strives to reach the efficiency of the human brain. Although scientists have researched the human brain for centuries, a large majority of it remains a mystery and within its depths lays the possibility to develop more efficient AI technologies. Nevertheless, the implementation of well understood brain functions—like edge detection and object recognition—in a combination of software and hardware might lead to the development of such technologies. In a previous project a software model was implemented simulating the neural network for orientation selectivity of the eye, reading from a live streaming webcam and assigning a degree of confidence for the angle detected in the image frame. In order to optimize that software, our team worked together to migrate the software from C++ language to MATLAB, thus, incorporating the ability to implement the new code in hardware. In addition, we used Gabor filter functions for edge detection which allows the detection of multiple edges in the same image; an important improvement to the previous version of the software. Another important improvement was the use of multiple simple and complex cell functions to scan the image frame, allowing for better simulation of the biological brain function. This project can be expanded by implementing the code in hardware and feed its output to a self-trained artificial neural network to complete the object recognition function.

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Incorporation of Amateur Radio Elements Into the Electrical Engineering Curriculum

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The amateur radio service was created to allow for public use and experimentation with one of our key natural resources, the electromagnetic spectrum. In order to use this public resource, individuals must pass a Federal Communication Commission (FCC) examination with technical and operational questions. There are over 2 million licensed to use the amateur radio spectral allocation.[1] The amateur radio community offers a wealth of practical hands-on educational materials that can be adapted into college laboratory curriculum.

The incorporation of amateur radio into the Electrical Engineering curriculum started with administering the amateur radio technician level examination as part of the first-year engineering curriculum. This was all made possible by the removal of the Morse code requirements for the examination in 2005. Students are required to study the 400 question examination pool supplied by the FCC and pass the official examination as a mid-term examination in the freshman orientation class. The Amateur Radio Club on campus along with community volunteers makes the midterm examination an official FCC licensing event. Over the most recent 4-year period over 500 students obtained their license to use the public spectrum. Projects created by the amateur radio community were incorporated into the formal and informal curriculum for the department to take advantage of the newly FCC licensed students.

For the formal curriculum, amateur related projects were incorporated into laboratory courses. Laboratory assignments included design, build and test of an electronic spectrum analyzer, filters, transmitter systems, antennas and radar experiments linked to the amateur radio spectrum.
For the informal curriculum, the Amateur Radio club on campus took the lead. The creation of 130 new licensed students each year with the freshman licensing initiative created a strong membership source for the club. Over a multiple-year time frame, a critical mass of experience and mentorship developed to make the amateur radio community vibrant on campus. In turn the campus amateur radio club created its own informal curriculum. The club hosted study sessions to help the students understand the question pool that is used to pass the FCC examination. After freshmen licensing, the club created an introductory project set and a low cost equipment rental program to provide a first hands-on experience. More advanced activities included radio construction projects, direction finding competitions, antenna builds, international space station contacts, and public service communication events. The public service event for the amateur radio student community is to construct that primary communication infrastructure for the wildflower triathlon at Lake San Antonio in April/May each year (30,000 in attendance).

Informal assessment of incorporation of amateur radio into the electrical engineering curriculum includes strong membership growth in the amateur radio club on campus, increased interest in the rf/microwave/communication concentration of the curriculum, and a devoted group of licensed Alumni who come back to campus each year to participate in the wild flower communication event.

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Evaluating Effects of Delays on Real-Time Hybrid Simulation of Seismic Response of Large Civil Structures

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Analyzing and evaluating seismic response of large-scale civil structural specimens can be very costly and difficult. One alternative to testing large-scale specimens is real-time hybrid simulation, which is an experimental method to evaluate structural dynamic behavior by combining physical and analytical models. Therefore, only parts of the structures are experimentally tested. However, time delay, which reduces the accuracy of the experimental results, is inevitable due to the actuator hydraulics. The purpose of this project is to evaluate the effects of delay by comparing delayed and actual responses. MATLAB and Simulink are used to simulate the analytical and the experimental model responses for different cases of degradation. For 100 ground motion records and a maximum considered error, critical delay is calculated and its lognormal distribution parameters are determined. Knowing the actuator's delay and using lognormal distribution graph of the critical delay, the probability that experimental error is less than the target error can be determined. This project, conducted by a group of community-college students, not only allowed exposure to civil engineering concepts and practices through the perspective of earthquake engineering, but also provided useful teamwork skills. Throughout their ten-week summer internship, the team members developed their time management through organization, communication and teamwork skills by collaborating their individual findings, and preparation for technical group reports with their research of articles.

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Wall of Moments: A Hands-On Platform for Developing Intuitive Understanding of Moment Arms

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The moment arm is one of the most basic physics concepts used in many fields of engineering, yet conceptual understanding of a moment eludes many undergraduate engineering students. While it is undoubtedly important for students to understand moment arms mathematically, we feel it is equally important for them to be familiar with their behavior from a qualitative standpoint. The Wall of Moments is an interactive exhibit taking the form of a large peg board into which various pieces of acrylic shapes from physics problems are fastened. Students may pull on various points of different crank shapes or lever configurations with a spring gauge in order to familiarize themselves with how linear forces convert to moments depending on the location and direction of applied forces. The goal of the Wall of Moments is to develop in students an intuitive understanding of the behavior of moments through first hand experimentation with such rigid bodies. It is important to clarify that our intent is not to confirm the theory with experimentation but rather we aim to have a student formulate their own theory about moment arms based off their interactions with the Wall of Moments. For this reason, it is very important that students are able to treat the data that they gain from the exhibit as reliable so that they may feel more inclined to trust their intuition when analyzing systems with moment arms. To achieve this end, the Wall of Moments must possess several key features: it must invite students to experiment on their own, it must be able to quickly verify theories formed by students, and it must provide results that are easily interpreted (i.e. for a 2:1 moment arm ratio, a force ratio of 1:2 is obtained rather than one of 1:1.7). We prompt students to use the exhibit by presenting them with a moment arm problem presented on paper as well as on the board. We also aim to encourage students to interact with the exhibit by the visual design of the components of the exhibit.

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The Future of Circuits and Systems Education

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In 1965, Kenneth Smith, the author of the popular textbook "*Microelectronic Circuits*", arrived at the University of Toronto and took over a position once held by Ed Red, a renowned practitioner and teacher of vaccum tube electronics. Kenneth Smith, along with his doctoral student Adel Smith, later revolutionized the circuit and system education by adopting an inverted teaching pedagogy sought to teach circuit concepts first before teaching physical electronics [1]. The so called top-down approach began with applications of op-amps, and gradually descended to transistor-level design. Sedra and Smith published their teaching pedagogy with the writing of *Microelectronic Circuits*, which has become the standard textbook worldwide with a million copies sold in 1982, seventeen years after Smith's arrival in University of Toronto.

In 1998, Yannis Tsividis became one of the first circuits and systems educators to notice the need for updating teaching methods in the field of circuits and electronics in light of changing backgrounds of incoming students at Columbia University in the late nineties [2]. Tsividis noticed that the so called students of the generation X were different from the students in the sixties. Whereas many students in the sixties grew up with ham radio, kit stereo, very few students from the generation X "tinkered", or played with electronics. Many were "impatient" and believe that "software was everything". He designed a first year lab/lecture that sought to encourage tinkering and used music as a universal experience to draw students to circuits [3]. He was credited with having reversed the decade long reduction in the EE department and doubled the EE enrollment in three years at Columbia University.
Many innovations have occurred since 1998. The arrivals of smart phones, iPad, around the clock internet access have created expectation of instant gratification among students of generation Z. The pedagogies developed in earlier times are no longer satisfactory for the attention span of today's students. Students today seem to be more interested in microcontrollers such as Arduino and Rhasperry Pi as opposed to Op-amps.

Creating an up-to-date top-to-bottom circuit curriculum that attract students who grew up in the Maker culture while adequately preparing them for industry jobs after graduation is an important issue for today's circuit educator. In this poster, we will review the changing landscape in circuits and system education in the U.S., propose an alternative curriculum, and examine its potential implementation in today's educational environment.

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STEM Transfer Success: Contributing to a Multi-Campus Collaboration

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A public four-year university has teamed up with three community colleges to collaborate toward science, engineering, and math student transfer readiness, transition, and academic success. Unlike many STEM collaborations between two- and four-year institutions, this project involves a coordinated infrastructure of administrators, faculty, and staff at each of the campuses involved. The program aims to provide academic and social interventions supported by a robust IT system, refined to increase support for articulation and transfer. While the project involved multiple institutions, the focus of this study is on one community college partner's STEM transfer success and its contribution to the larger project.

The overall project grant began in fall 2011 and will be in effect through fall 2016. The program was implemented at the community college in spring 2012 and welcomed their first STEM students in fall 2012. The project is in alignment with the purpose of SB 1440.

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Closed-Loop Feedback Temperature Controlled Encasement to Test The Optimal Temperature for Poly Lactic Acid (PLA) and Acrylonitrile Butadiene Styrene (ABS) Polymers for The PunchTec Connect XL 3D Printer

William Berrios[1], Colin McGill[1], Giovani Rodriguez[1], Jeremy Chow[1], Michael Kinsler[2], Kwok-Siong Teh[2], Amelito Enriquez[1]

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This poster presentation is a description of a project done by a group of freshmen and sophomore community college students during a ten-week summer internship program funded by NASA through the Curriculum Improvement and Partnership Awards for the Integration of Research (CiPair) program. The goal of the project was to improve the quality of 3D prints for a Punchtec Connect XL 3D printer by designing and building a temperature-controlled enclosure to minimize the effect of variations in environmental temperature. The enclosure was built using an acrylic frame, an Arduino microcontroller, a CPU fan, a thermocouple, an LCD digital display, and heating elements. To determine the effect of the enclosure on the print quality, tensile tests were performed at various temperatures and results with and without the enclosure were compared. Preliminary test results show that the enclosure did not significantly improve the strength of the print. Further testing could be performed to analyze other characteristics such as resistance to delamination. A post-program participant survey indicates that the internship was successful in helping students develop problem-solving skills, increasing student interest to further engage in research activities, and enhancing student self-efficacy for successfully transferring to a four-year university and competing a degree in engineering.

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MENTORES

Mentoring, Educating, Networking, and Thematic Opportunities for Research in Engineering and Science

Promoting Post-baccalaureate Opportunities for Hispanic Americans (PPOHA) | U.S. Department of Education

Behnam Bahr, Lily Gossage

California State Polytechnic University, Pomona

California State Polytechnic University, Pomona (Cal Poly Pomona) proposes a comprehensive educational project, MENTORES (Mentoring, Educating, Networking, and Thematic Opportunities for Research in Engineering and Science), for increasing the number of Hispanic, under-represented minority (URM), and low-income students earning master's degrees. Currently, Hispanic students represent 37% of its undergraduate enrollment and 28% of its graduate enrollment. By eliminating institutional gaps that inhibit graduate school entry, retention, degree attainment, post-graduate employment, as well as acceptance into Ph.D. programs, MENTORES will expand existing services/programs within the university in order to produce a talented pool of professionals and leaders for the STEM workforce. Though the project will be focused on California's acute need for a skilled workforce, specifically trained in water/energy infrastructure development, it can include other urgent multidisciplinary issues requiring STEM solutions. At Cal Poly Pomona, the Colleges of Engineering, Science, Agriculture, Environmental Design, Letters, Art, and Social Science will participate in this project; it is a veritable campus-wide project with strong support from the Office of the Provost. Key personnel will come from the departments of civil engineering, geological sciences, biology, chemistry, and urban/regional planning; faculty in these disciplines believe that this project will meet their department's educational objectives for producing the *best and brightest* in the STEM workforce. Particular emphasis on collaboration with the Lyle Center for Regenerative Studies, the university's premier sustainability project, is envisioned. The new Environmental/Water Resources graduate program—which requires faculty, lab facilities, and expertise across a broad range of disciplines—is the ideal prototype for this project. Consistent with Governor Brown's emphasis on developing sustainable water/energy supplies for the state (in the face of severe drought, climate change, and population growth), is the university's pledge for meeting California's goal to reduce water/energy consumption by 20% within the next six years. This project will greatly enhance Cal Poly Pomona's efforts to meet this ambitious goal by harnessing the full intellectual power of STEM faculty and graduate students on the problem of water/energy sustainability on campus while meeting urgent societal needs. MENTORES will:

- Identify talented and promising Hispanic, URM, and low-income students;
- Assist students to enter master's degree programs by marshaling a variety of resources;
- Assist students to successfully earn master's via enhanced mentoring and other services;
- Develop and prime the pipeline of Hispanic, URM, and low-income students into competitive doctoral programs (such as UC Berkeley, UCLA, Cornell, and MIT);
- Educate faculty about the cultures and needs of students;
- Expand the Learning Resource Center to better serve graduate students;

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- Expand the Maximizing Engineering Potential (MEP) and Science Educational Enhancement Services (SEES) programs;
- Expand Library and Writing Center services to serve unique needs of graduate students;
- Strengthen and broaden relationships with industry and government agencies through the Career Center to expand students' opportunities for paid research/internships;
- Provide financial aid, research stipend, and travel support for students;
- Upgrade existing laboratory facilities to better support specialized research and training;

Develop online courses to optimize access and fle

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