Pacific Southwest Regional ASEE Conference

Transforming Engineering Education through Community Engagement, Entrepreneurship and Service Learning

California State University, Fresno
Fresno, CA 93740
March 31 – April 2, 2011

Lyles College of Engineering
California State University, Fresno

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Conference Proceedings

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(WIP) – Indicates a Work in Progress

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Pacific Southwest Regional ASEE Conference

Configuration of Senior Capstone Course Using Team-Teaching to Maximize Communication Skills and Minimize Team Conflict

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Senior capstone courses instructed at Embry-Riddle Aeronautical University, Prescott campus, incorporated team-teaching between Aerospace Engineering/Mechanical Engineering (AE/ME) and Humanities and Communications (HU/COM) instructors in spring, 2003[1]. By 2009, HU/COM instructors were team-teaching in all six (6) senior capstone courses. The senior capstone course which is considered the model for all others at this university is AE 421: Aircraft Detail Design; AE 421 has been team-taught by the same AE instructor and COM instructor for the past eight years.

AE 421 requires student design teams, formed in a previous semester and each led by a design team lead, to verify aerodynamic and stability predictions through wind tunnel testing, predict the structural response to load of an aircraft component (e.g., a wing section) through analysis and simulation, and attempt to verify the structural response predictions through the manufacture and test of a test article representative of the component. A design-build-fly option is also available for some teams who choose to further evaluate their designs through flight test. All teams must document their work, both in writing and in a series of formal presentations. Because of the numerous objectives and tight schedule, AE 421 is a high stress environment that can lead to conflict between team members, conflict which might hinder student productivity. To maximize student communication skills and to minimize team conflict, AE 421 is strictly organized to provide students four primary activities during each class period: technical lectures from the AE instructor, writing and presentation lectures from the COM instructor, team meetings led by the design team leader, and open work time.

The first objective of this paper is to detail the configuration of AE 421 as a team-taught senior capstone course. First, team teaching will be defined and its benefits in an engineering education context will be described[2]. Benefits to student communication skills, particularly documentation and conflict negotiation skills, will specifically be addressed. Then, the segmentation of each class meeting into four primary activities will be discussed, as will the nature of these primary activities; a rationale for each activity will also be offered. Next, key alterations made over the past eight years in order to improve the class will be identified.

Although this team-teaching configuration is of demonstrable value to students in their academic and professional careers [3], alternative configurations have been introduced at this and other universities over the last several years. A second objective of this paper, then, is to argue the merits of this particular team-teaching configuration. Specifically, the critical role of communication instruction in the senior capstone course will be addressed, as will the role of the communication instructor. Finally, an argument will be made that this team-teaching configuration has improved engineering students' writing skills and their ability to negotiate conflict with students on their design teams.

History and Goals of Team Teaching

Team teaching is a collaborative teaching effort in which two or more faculty members deliver the content of a single course, sharing the burden of course preparation, lecture, in-class tasks, and assessment [1, 2]. There are several different team-teaching configurations ranging from a course in which the primary instructor receives help from a supporting instructor in the form of occasional lectures to a course in which two instructors equally share in all course planning, lecturing, monitoring of activities, and grading tasks. As will be recounted in the following paragraphs, this second configuration was adopted for AE 421.

Eight years ago, the AE faculty responsible for teaching AE 421 approached the campus' HU/COM instructors and asked for help in addressing students' weaknesses in communication. Specifically, although they were seniors poised to graduate and enter industry, students needed to refine their skills in writing technical documents such as test plans and test reports and in giving formal presentations. In other words, the AE faculty requested help in meeting ABET outcome "g" which states that "Engineering programs must demonstrate that their students attain...an ability to communicate effectively" [4]. Later, AE faculty would work with COM faculty to meet ABET outcome "d" which states that "Engineering programs must demonstrate that their students attain... an ability to function on multi-disciplinary teams" [4]. Both technical communication and teamwork skills thus became the focus an AE/COM collaboration.

After examining the problem, the AE and HU/COM departments decided to experiment with a team-teaching venture. AE 421 was chosen as a test case in part because it is a model for all other senior design courses at Embry-Riddle Aeronautical University, Prescott campus, and in part because this course is both writing intensive and presentation intensive and students could benefit from supplementary COM instruction. Moreover, it later became apparent that due to the demanding nature of this course, students are often stressed and this stress can lead to interpersonal conflicts between team members. It was thus argued that students could benefit from supplementary COM instruction in conflict negotiation and resolution. By inviting a COM instructor into the senior design course, COM support could be deeply embedded in the students' capstone experience, providing timely instruction just before graduation. In order to maximize the COM instructor's understanding of the engineering students' needs, and in order to provide students with maximum access to COM instruction, it was decided that the COM instructor would attend every class meeting, would share equally in lecturing and other classroom tasks, and would have significant grading authority.

In order to provide a team-taught class which tightly integrated engineering and communication instruction and practice, the class was strictly organized as discussed in the following section.

Organization of Class Sessions

AE 421 meets twice per week for 2 hours and 40 minutes per class meeting (i.e., for 5 hours and 20 minutes per week). Both team teachers attend all class meetings. Each week's instruction is organized to include four (4) primary activities, each designed to target some specific aspect of engineering or communication education. These activities include engineering lectures, communications lectures, team meetings (which include a status report and an informal briefing), and open work sessions.

The first activity is an engineering lecture, given by the AE professor the first class meeting of the week. This lecture lasts approximately 1 hour and is carefully designed to provide timely reminders of key concepts, processes, and equations that students are most likely to use in the coming week. As previously mentioned, one of the primary purposes of the class is for teams to verify loads predictions through the manufacture and test of a test article representative of an aircraft component. Thus, one engineering lecture might be on how to undertake a materials trade study, including calculation of strength-to-cost efficiencies and determination of the impact of various materials on the environment during manufacture or disposal; this lecture would be given prior to the ordering of materials and manufacturing of the test article.

The second activity is a communications lecture, given by the COM professor the second class meeting of the week. This lecture lasts approximately 45 minutes and provides guidance in public speaking, documentation, conflict resolution, and whatever similar topics need to be addressed that week. Typically, the communication lecture focuses on the specific documentation that is to be submitted in the following week and provides a rich outline, with examples, of the type of text to be written so that students have a model upon which to base their own writing. Specific instruction on use of proper technical language and graphical support is also provided. Thus, one communication lecture might focus on how to construct an effective comparative table and how to cite OSHA documentation; this lecture would be given the same week as the engineering lecture mentioned in the preceding paragraph. Note that both sets of lectures are intended to be complementary and of immediate practical use to prepare students for the engineering and communication tasks that they face in this senior design class as well as those that they would face in industry.

The third activity is a team meeting; each design team typically consists of 6-8 students (or for design-build-fly teams, 12-16 students) and each team meets once per week during class, typically for approximately 30 minutes. The team lead runs the meeting and at least one team teacher attends each meeting. These team meetings are highly structured. First, the team lead provides a written agenda for the meeting, and then reviews the forthcoming tasks assigned to each team member using a Gantt chart. Then, in roundtable fashion, each team member gives a status report to the team, focusing on the tasks accomplished last week, the tasks to be completed in the coming week, and any problems or issues they are having and need help with. Because design teams can be rather large and because students tend to become highly focused on their own set of tasks, these status reports serve to keep the team connected and to ensure that any problems with the project are publicly voiced and publicly resolved. Both team teachers ask questions and provide input as necessary, guiding the teams to consider issues that they otherwise might not have.

After the status reports, one student will give an informal PowerPoint briefing to the rest of the team on a critical topic for the week. Thus, if the team is working towards the wind tunnel test, a team member might brief the rest of the team on the wind tunnel model fabrication or on the test procedures. This informal briefing has several purposes. It allows teams to communicate progress on critical tasks; if there is an obstacle or issue, it provides team members a chance to ask for or offer help or ideas for resolving the issue. It also allows students additional opportunities to practice their public speaking skills, which as previously mentioned was identified as an area of student weakness when this team-teaching venture began. By the end of the term, all team members will have given at least one informal briefing. At the end of the team meeting, the COM professor privately critiques the student who gave the briefing and helps them develop strategies for improving their public speaking skills. Finally, each team meeting ends with a review of the action items for the week. Note that the primary goal of the team meetings is to maintain open lines of communication between students as their design project progresses so that technical problems are addressed and resolved; with the institution of formal team meetings and informal briefings, not only have the overall quality of the various design projects improved but also the frequency and severity of interpersonal conflicts has been minimized.

The fourth and final activity is an open work session. During this activity students are free to work on their tasks, whether analyzing, manufacturing, testing, or documenting; both instructors are available throughout the work session to help with either technical or communication tasks. If team members are having trouble working together, then this time is also used to meet privately with the students in question in order to mediate these conflicts. This addition of conflict mediation is one of the key improvements to this team-teaching configuration as will be discussed in the following section.

Key Alterations and Improvements

Each semester since the beginning of this team-teaching venture, the impact of the presence of a COM instructor in the senior capstone course has been assessed; in addition to reviewing their own notes and sharing their own observations, the team teachers typically review student course evaluations as well as comments and suggestions made by recent alumni, by members of the college's Industrial Advisory Board, and by support staff (e.g., the Machine Shop Manager). Each semester challenges have been identified and alterations have been made in response to these challenges in hopes of improving AE 421, with particular focus on how to more deeply and seamlessly embed communications instruction and support. Some of these challenges are institutional in nature (e.g., how to appropriately credit both instructors for time spent inside and outside the classroom) and are outside the scope of this paper. Those challenges that are pedagogical in nature and the resulting alterations/improvements are discussed below.

One of the key challenges faced by the course instructors was how to most effectively teach students the specific documentation style required in AE 421; documentation is critical in this writing-intensive course, but it is in fact a design course, not a writing course. In addressing this challenge, the AE and COM instructors decided the best approach would be to invest class time in weekly communication lectures (rather than, say, merely provide reference notes or models on Blackboard). These team teachers developed a process by which the communication lectures were co-constructed by both teachers.

Initially, the AE instructor provided models of documents written by students in past semesters and deconstructed them with the COM instructor, noting what was desirable based on his extensive experience in industry and in the classroom. In turn, the COM instructor noted specific textual elements that were aligned with the college's articulated standards for documentation and which should already have been familiar to students from their sophomore-level technical writing classes which she had taught for several years. Over time, the two instructors were able to define a formal outline for each document required by the class. Then, they went beyond basic outlines and identified critical rhetorical and textual elements for each document including expected content, language, graphics, and formal stylistic elements. These elements were codified in a series of lectures initially written by the COM instructor, with models and templates included. These lectures were reviewed and revised by the AE instructor so as to most accurately reflect the expectations of the college and of industry. Eventually each lecture was "finalized". Both instructors continue to jointly review and revise these lectures each semester, refining them in response to student needs.

On the one hand, the instructors' response to this first challenge resulted in lectures that are tailored to AE 421 and that provide students with specific and helpful guidance regarding course expectations for documentation. On the other hand, the instructors' response illustrates the critical nature of frequent and prolonged communication between team teachers if they are to be successful. Arguably, team teaching is not merely the division of teaching tasks between two or more teachers, nor even simply the creation of a classroom where students have access to the expertise of two or more instructors. Instead, team teaching is the co-construction of a class such that the expertise and skills of both instructors are effectively interwoven into the class' organization, activities, tasks, and feedback mechanisms [1, 2]. Such co-construction requires frequent, clear, and honest communication between instructors. Moreover, to successfully co-construct a course both instructors must feel comfortable sharing authority in the classroom. This type of teaching relationship, where both teachers are co-equal, is one of the great strengths of AE 421. Again, however, frequent and respectful communication is necessary to achieve this end.

A second key challenge that the team teachers faced was how to more effectively support students' public speaking skills. In addition to written documentation, AE 421 requires that students make formal team presentations at midterm and finals to panels of experts from the college and from industry. These presentations are open to the campus and the larger community. Although teams were given a class period for practice runs before both the midterm and final presentation, and although faculty gave both verbal and written feedback after the practice runs, students were not getting sufficient practice in public speaking, especially in comparison to the rich amounts of practice in written communication.

To rectify this problem, the team teachers decided to incorporate informal briefings into the team meetings. As previously noted, these briefings are intended to be not only an opportunity for a student to publicly notify team members of the progress made and problems encountered in a certain task but also to seek help. It is this last element that makes these briefings extremely useful to the teams as the informal briefings more often than not serve as springboards for wider discussions that allow the team to solve pertinent design problems. In the meantime, each student also gets supplementary communication in a low-risk environment (as opposed to the midterm and final presentations which contribute significantly to their grade) as well as timely personalized feedback from the COM instructor at the end of the meeting. Thus, the inclusion of briefings in team meetings was a small change to the structure of the team meeting that has had many positive returns.

A third key challenge that the team teachers faced was how to best deal with a high stress classroom environment. Most students enrolled in AE 421properly view their capstone project as the culmination of their undergraduate career. These projects are typically multifaceted and require significant investments of time and attention by all members of a team to reach completion; a few of the critical tasks undertaken in a single semester are the fabrication and test of wind tunnel models, the analysis of wind tunnel results and comparison to aerodynamic and stability predictions, the prediction of design loads on a critical aircraft component (e.g., a wing section), the completion of material trade studies, the modeling and simulation of the structural response of the critical aircraft component to the predicted loads using finite element methods (FEM), the creation of a drawing package, the manufacture of the critical component, the structural test of that component, and the analysis of structural test results and comparison to FEM predictions. As is obvious from this abbreviated list, there are multiple, demanding tasks that must be completed in a short period of time (approximately 15 weeks). Furthermore, many of these tasks cannot be begun until others are finished, which creates a domino effect. Finally, students obviously have other demands placed on their time (e.g., other classes, work, families) and so proper time management is critical.

Given this high stress environment, it is not surprising that interpersonal conflicts often arise during class, typically in regards to how one student perceives another as "slacking" or not holding up their end of the workload and thus delaying the team's progress. In response to these interpersonal conflicts, the AE and COM instructors developed a conflict resolution process;

students are instructed in this process early in the semester and sign a code of conduct which states that they will follow this process should conflicts arise. The conflict resolution process is one which anyone will be familiar with if they are experienced working in industry, academia, or another institution for any length of time but which students are often unfamiliar. The process can be summarized in a few steps as follows:

1. Should a conflict occur, talk to the person involved privately.

2. State specifically what the conflict is and how it is impacting the work.

3. Do not make any *ad hominem* attacks. Focus on the issue, not the person.

4. Give the other person equal time; actively listen.

5. Attempt to reach an accord that clearly states any action to be taken from now on.

6. All discussions are to be kept confidential between the involved parties.

7. Monitor the situation; if warranted, begin the process again but this time ask the team leader to mediate the conflict.

8. Monitor the situation; if warranted, begin the process again but this time ask the course instructors to mediate the conflict.

Since this process was adopted in AE 421, the number of interpersonal conflicts has significantly dropped and the severity of these conflicts has generally been minimized. Although conflicts will always occur, especially in such high stress situations, it is critical that students learn strategies for negotiating and resolving conflicts, strategies that allow them to self-mediate when possible and to learn to ask for mediation when not.

The challenges discussed in this section are by no means the only ones faced, but they are three of the most critical ones that are communications-based. The team teachers were able to meet these challenges in great part because of how this class was configured, i.e., both instructors were present for each class, both instructors spent a significant amount of time out of class working with each other to co-construct the class, and both instructors shared responsibility for providing course material, for assigning and monitoring tasks, and for assessing the students and the success of the team-teaching venture itself. The success of team teaching in AE 421 has led to the spread of team teaching into every other senior design course at Embry-Riddle Aeronautical University, Prescott campus (and to courses in other colleges on campus as well, such as the College of Aviation). Not all team-teaching configurations have been identical, however, and are dependent on the negotiation between the AE and COM instructor. The resultant configurations are further defined in the following section.

Alternative Configurations

As demonstrated in AE 421, COM instructors play a key role in engineering education at Embry-Riddle Aeronautical University, Prescott campus. Team teaching has become a valued pedagogical approach at this campus, with some alternative configurations being attempted over the past few years [5]. Two configurations will be discussed in this section: the "co-equal" configuration which has been described throughout this paper and the "consultation" configuration. These two configurations are compared against each other in the following table:

Table 1: Alterative Team-teaching Configurations

	Co-Equal Configuration	**Consultation Configuration**
Does the COM instructor attend every class?	YES	NO
Does the COM instructor help interview and select the team leads?	YES	NO
Does the COM instructor have lecture authority?	YES, weekly	YES, occasionally
Does the COM instructor work with the AE instructor to co-construct lectures and other course material?	YES	NO
Does the COM instructor read multiple drafts before assigning final grades to documents?	YES	NO
Does the COM instructor attend team meetings?	YES	NO
Does the COM instructor mediate team conflicts?	YES	NO
Does the COM instructor have grading authority?	YES	YES
Does the COM instructor attend and grade midterm and final presentations?	YES	YES

As the preceding table indicates, the consultation configuration treats the COM team-teacher as a resource for the class rather than as a teacher of record; as such, they can be incredibly valuable. First, they provide the occasional lecture on documentation and presentation style on an as-needed basis, lectures that they have created based on their experience as technical writing instructors. Second, they assist the AE instructor by helping to grade the final documentation. Third, they assist the AE instructor by helping to grade the midterm and final presentations.

However, their integration into the AE class is minimal and therefore, minimal communication assistance is provided to the students.

Of note, COM instructors working under the consultation model do not attend every class and in fact, often do not attend class at all unless they are giving a lecture that day. Even when they do attend class they often leave after their lecture and do not participate in team meetings nor in conflict resolution sessions. This infrequent participation can lead to a lack of understanding of the projects the students are working on and of the communication and conflict-resolution needs of these students. Also of note, the COM instructor does not co-create lectures and other materials in conjunction with the AE instructor and thus their lectures may not reflect the specific needs of these specific students in this specific senior design course; furthermore, the requirements stated in the COM instructor's lecture may be at odds with the requirements held by the AE instructor, potentially leading to conflicts between the instructors themselves when it is time to assign grades to student documents or presentations.

The consultation configuration does have its merits; for one, it allows COM faculty, who may already be stretched thin by various obligations, to have a presence in one or more senior design courses and thus to provide communication support to a number of AE faculty. For another, this configuration can also be used by COM and AE professors who are working together for the first time until they can negotiate exactly how the COM professor will be more tightly integrated into the senior design course; as such, this configuration can serve as a gentle introduction to team teaching and its pedagogical possibilities and after a semester of negotiation, the consultation configuration can be morphed into a co-equal configuration [5].

Given that the co-equal configuration is time- and labor-intensive, that it requires constant communication and negotiation between the team teachers, that it involves frequent assessment and re-assessment of course materials, tasks, and teaching approaches to see whether communication objectives are being well and fully met -- given all this, the co-equal configuration is superior to the consultation configuration in that it provides communication support that is more thoroughly integrated with engineering education, is more pertinent to the immediate design tasks at hand, and is more balanced between writing, public speaking, and interpersonal interaction.

As an aside, students report in both course evaluations and senior exit interviews that they prefer to have a COM instructor in class full time (i.e., that they prefer the co-equal configuration), that the instructor then feels like a "real" teacher that they can ask questions of, rather than like a "guest" that they hesitate to bother. And several COM instructors report that they prefer to be in class full time, that they can provide better contextualized instruction if they are truly part of a teaching team and not playing the role of a teaching or grading assistant. These reports further strengthen the argument that a co-equal configuration for team teaching both benefits students' communication skills in senior design class and provides a superior arrangement to the consultation configuration. Further conclusions will be offered in the next section.

Conclusions

This paper has given a brief history of the development of team teaching at Embry-Riddle Aeronautical University, Prescott campus, as practiced between the AE and COM faculty in AE 421: Aircraft Detail Design. A description of the organization of this senior design class into four (4) primary tasks (i.e., engineering lecture, communications lecture, team meetings and informal briefings, and open work sessions) was provided; three of the key alterations made to AE 421 in the last eight (8) years to improve lecture material on required documentation, to provide more frequent opportunities for students to practice public speaking, and to codify procedures for negotiating and resolving conflicts between students were also discussed. Alternative arrangements for team-teaching were compared, and the argument was made that the co-equal configuration is superior to the consultation configuration.

In closing, this 8-year old team-teaching venture has highlighted the critical role of the COM professor in the senior design courses. When COM instructors began team-teaching in AE 421, AE and COM faculty assessed student documentation and presentations and identified several areas of weakness. For written documentation these weaknesses included the ability to organize a persuasive argument based on technical data, to write a clear and concise abstract, to present information graphically and comment on this information in prose without "data dumping", and to use appropriately formal language. For formal presentations these weaknesses included the ability to craft a PowerPoint presentation that engaged the audience, to create a narrative thread in a team presentation, to address an audience of technical experts and lay members and satisfy the curiosity of both, and to use appropriately formal language.

For the past 8 years, AE and COM faculty have assessed student documentation and presentations, comparing student products created at the beginning of each semester to those created at end of semester; these assessments indicate that these students do indeed demonstrate growth in most of the aforementioned areas. While these assessments have been primarily qualitative in nature, student feedback in terms of course evaluation and senior exit interview comments indicate their concurrence with this appraisal. As there have been few other significant pedagogical changes to the senior design courses, these improvements can be attributed in part to the team teaching arrangement that has been introduced to these classes (and all of the subsequent changes that have been made, from co-constructed lectures to the inclusion of informal team briefings to the adoption of a conflict resolution process that lets students work through interpersonal differences and get to the work at hand). Furthermore, the introduction of a clearly articulated conflict negotiation process has reduced the frequency and severity of interpersonal conflicts in the senior design courses.

Arguably, then, team teaching provides students with timely supplemental instruction in technical writing and formal presentations and conflict mediation. Other colleges may wish to begin their own team-teaching venture with the consultation configuration until they become more familiar with the benefits to engineering education that team teaching provides and develop a co-equal configuration that best supports their students' communication needs. At Embry-Riddle Aeronautical University, Prescott campus, team teaching has proven so successful that it has been institutionalized, i.e., team-taught courses have been adopted into the undergraduate catalog for the College of Engineering. While every engineering program has its own unique student body and mission, if AE and COM faculty are willing to work across disciplinary lines to negotiate the most effective ways to help students refine their communication skills just before entering industry, team teaching can be a very valuable pedagogical approach.

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Investigation of a Masters Research Project for Validation of Program Goals and Student Learning Outcomes

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Abstract

Browsing on the web, shopping online, sending SMS messages, checking e-mail, transferring multimedia data, playing games, listening to music, watching movies, socializing, and controlling devices or equipment through smart mobile phones are now routine Internet activities. Wireless applications in areas such as communications, data transfer, system automation, public safety, e-business, education, healthcare services, entertainment, travel services, information services, and shopping, are, likewise, commonplace. Mobile Applications (Mobile Apps) have been developed and are available for both personal and business use. Currently, the number of available robust Mobile Apps compared to PC-based applications is limited. In order to meet increasing consumer demands many more Mobile Apps need to be developed. This paper analyzes the growth of wireless communication in society, business and education, and describes how National University is meeting the need for increased application development skills in its engineering curricula. In 2004, National University initiated a unique Master of Science in Wireless Communications (MSWC) program, in order to better prepare wireless communications professionals. To date, many cohorts of students have graduated from the MSWC program and are now actively contributing to the field. In order to meet the degree requirements, students of MSWC are required to complete a relevant research project that is the deliverable product of the Capstone course. This paper i) investigates the outcomes of a recently completed student Capstone project "Smart Phone Book Search", ii) analyzes how the students met the program goals and gained practical experience dealing with real life problems, and iii) demonstrates how the project provides a viable solution.

In the current busy Internet world, we are all actively engaged in a great variety of different pursuits and heavily dependent on our mobile phones to maintain immediate contact with family, friends, and colleagues. We often store information in our mobile phones and later randomly retrieve such information as needed. Contact information stored in our mobile phone is used for a variety of purposes beyond making a phone call, and serves as an important general purpose data source. The "Smart Phone Book Search" project addressed the specific issue of when a mobile user, suddenly without his/her phone, needs important contact data stored in the phone. How can such a user retrieve the desired information from another accessible mobile phone? A solution to this problem was proposed and implemented by the students in this new Mobile App.

This application is capable of accessing contact data stored in a mobile phone and retrieving the information remotely by sending an SMS message.

Key Words: Mobile Apps, SMS, GSM, CDMA, Internet, Symbian, Platform, and 3G Networks

Introduction

In October, 2010, the International Telecommunication Union (ITU) issued a press release and published statistical data on mobile phone usage. Access to mobile networks was estimated to be available to over 90% of the world population as 143 countries offered 3G services[1]. With a world population in excess of 6.8 billion the total number of mobile users is estimated to be 5.3 billion[2,3]. Currently, 940 million people have access to Mobile Broadband to browse on the internet using mobile phones and 1.6 billion people have access to the regular Internet through fixed line connections[4].

Mobile Communication has been a relatively recent innovation that empowered people to have access to information anytime, anywhere. The initial cell phone started off as an electronic device for voice calls. This technology broadened its offerings to text messaging, web browsing, Bluetooth, camera, video recording and other multimedia message services. The possibilities are endless with the latest phones offering maps, navigation, high speed internet (3G), digital organizer, Wi-Fi connectivity and touch screen operation. The runaway success of this industry is attributed to constant innovation that provides newer and better features for mobile phones. Recently published data explains how much revenue is generated through SMS: *"In 2009, worldwide SMS revenue stood at a staggering USD 102.3 billion and this is forecast to grow to over USD 109 billion by end-2010. Annual worldwide SMS traffic volumes rose to nearly 5.5 trillion SMS at end-2009, and total SMS traffic will break 6.6 trillion in 2010. Highly impressive growth will continue from there[4]".* Users, constantly on the go, want their device to acquire contact, maps, weather reports, news, and entertainment information. One of the most economical technologies for incorporating these needs is Short Message Service (SMS)[5]. This was originally designed and developed as part of the Global System for Mobile (GSM) Communications standard. SMS enables mobile-to-mobile exchange of short messages using standardized communication protocol. Besides GSM, SMS is now widely used by other 3G networks including Code Division Multiple Access (CDMA), Digital Amps Network, and others.

SMS service is the most convenient way for sending text messages. This service is capable of sending important information such as news and emergency calls with minimal overhead. For example, an encrypted and digitally signed SMS is sent with minimum overhead of 3 SMS packets[6]. Furthermore, it has generated additional revenue for the telecommunications industry. This technology indisputably has achieved a tremendous success. As of today, many innovative applications have been developed. Therefore, mobile communication has a potential impact on message services. It satisfies the current and the future needs of billions of people. 'Smart Phone Book Search' is an application built exclusively for mobile phones operating on the Symbian

Operating System platform. This is a new Mobile App that retrieves contact information remotely from any mobile phone that can send an SMS message when a user forgets to carry his/her mobile phone and it was left in the ON state (referred to as “server mobile phone”). The retrieved contact information includes first name, last name, and mobile phone number. This application is compatible with Symbian OS v7.0 and runs on all mobile phones of the Nokia 6600 series[7]. The Nokia 6600 phone supports the vCard function and is capable of searching contact information stored in the database of the server mobile phone. The application is implemented using Symbian C++ code on Symbian OS version 7.0 platforms[8,9,10]. This specific mix of technologies enhances the effective data transfer of SMS messages. In this implementation, both single and multiple contact information may be retrieved.

‘Smart Phone Book Search’ is a Mobile App that executes on the server mobile phone. There is an ongoing debate over Browsers vs Mobile Apps. Whether users prefer mobile websites to apps is still unclear[11]. This solution, however, uses a Mobile App approach. The application program setup file is saved on a CD and then installed on the server mobile phone using the Symbian OS platform. This application runs constantly in the background when the server phone is ON. The client mobile phone, which will initiate the query via SMS, does not need to have the ‘Smart Phone Book Search’ application program. Furthermore, a query SMS message can be sent from any mobile phone. The application continuously tracks for any incoming SMS to the server mobile phone. Anytime there is a new SMS in the inbox of the server phone, the ‘Smart Phone Book Search’ program checks the content of the message and takes the necessary action. In this implementation, a password ‘SEARCH’ was used to trigger detection of a search string by the application. When a client mobile phone sends an SMS message string with the leading word ‘SEARCH’, the ‘Smart Phone Book Search’ application initiates a search for the specified string information stored in the server mobile. Once the requested information is found, the server mobile phone sends an SMS containing all the retrieved information back to the client mobile phone.

The System Block Diagram

Figure-1 shows the block diagram of the ‘Smart Phone Book Search’ system and explains how it works.

- SMS message must start with the password ‘SEARCH’. This is the first string in the message.
- The word SEARCH must be followed by a blank space and the name to be looked for in the database.
- The name should be followed by the character *

If the message is in a particular predefined format, such as, ‘SEARCH John *’, then the application reads the specified string after the word SEARCH. Once the keyword is verified, the application will begin to interact with the stored database in the server mobile and look for the required contact information. Once the requested contact information is found then an SMS containing the contact’s first name, last name, and mobile phone number will be sent to the client mobile phone that initiated the request.

The ‘Smart Phone Book Search’ application is installed using the Symbian OS Installer (SIS) file on the server mobile. After successful installation of the ‘Smart Phone Book Search’ application, the server mobile will keep checking all incoming SMS messages. To understand how this system works, consider the following example between double quotes: “SEARCH John*”. If this incoming SMS message contains the keyword ‘SEARCH’ at the beginning of the text string then the Mobile App will be triggered on the mobile server phone (it is already executing). If the incoming SMS does not begin with the password keyword ‘SEARCH’, the message is stored in the inbox. However, if the incoming message starts with the keyword ‘SEARCH’, the application will search for ‘John’ and retrieve all the information which matches the character string ‘John’. It will then create an appropriate output message string containing the first name, last name and the mobile phone number in a specified format and send the string to the client mobile. If there is no match found for the string ‘John’ then the application will create and send an error message to the client mobile. Finally, it will delete this current message from the inbox and outbox of the server mobile.

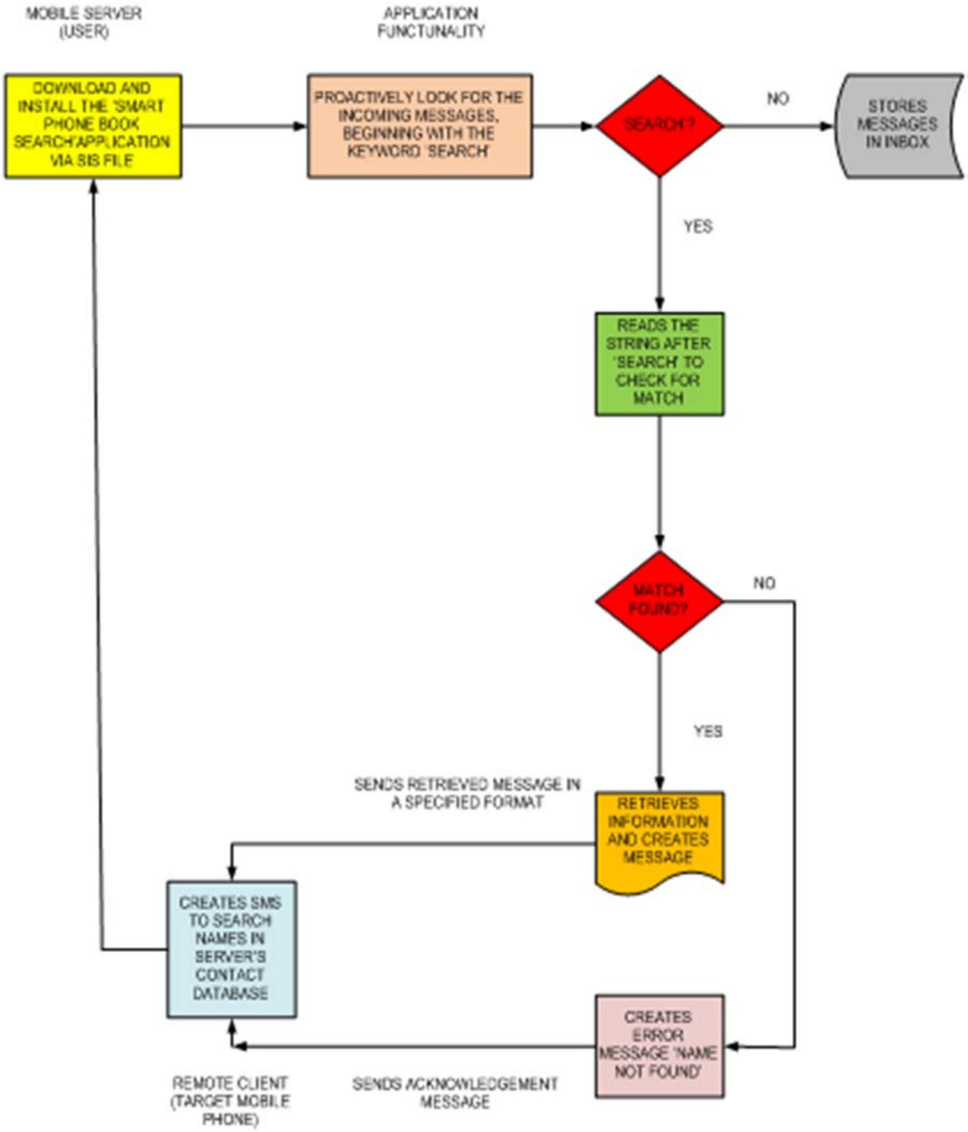

Figure-1: Block Diagram of Smart Phone Book Search[12]

System Functionality for Single Contact Query

The ‘Smart Phone Book Search’ application is designed to continuously track the incoming SMS messages on a Symbian-based mobile device. This is achieved by creating watchers using the SMS stack. Watchers are available in the communication protocol and are implemented using the ‘Smuthdr’ library[9]. Whenever there is a new incoming SMS, it checks the content of the message. The application is designed to read the message in a pre-defined format. It reads the string specified after the password ‘SEARCH’. Once the message is received, it also reads the mobile number of the target mobile phone. As discussed in the previous example, it will search for the string 'John' in the server phonebook. It picks up the contact numbers starting with the characters 'John'. Note that the characters used in the string are not case sensitive, because contact information might be stored using both upper case and lower case. The following message will be created by the application and sent to the client mobile[12]:

"John Miller 619-111-2222 619-444-5555"

If no match is found then the application will send an SMS 'Name not found' to the client mobile phone. In both cases, the application will conclude this process by deleting the associated messages from both the inbox and outbox of the server mobile. Under the normal operating conditions of 3G Networks, this whole process takes approximately 15 sec.

In this example, the keyword 'SEARCH' is the password that triggers a search. It is case sensitive and is used for authentication purposes. Password lengths must consist of a minimum of 6 characters in order to provide minimum security. Once the authentication is verified the application will send the response messages to the target mobile phone. At any point if the user wants to change the password, the user can go to the 'Smart Phone Book Search' application menu, select the option "Change Password" and enter the current password. If this entry matches the current password then another text box will be opened to allow the user to enter the new password. The application will then ask the user to re-enter the new password for confirmation and the password will be updated.

System Functionality for a Multiple Contacts Query

Different models of Symbian enabled mobile phones can store contact names in a variety of ways. The first name can be stored as last name and vice versa. Not only mobile phones, but people, tend to store names differently in the phonebook. In order to avoid this confusion, a wild card character '*' can be used which acts like a disclaimer. It succeeds with every name that needs to be searched and retrieved in all possible combinations related to that name.

The following commands depict some different scenarios in this project:

If all these names exist in the phonebook then the following messages will be created and sent:

- SEARCH *: Retrieves all the contacts present in the phone book.
- SEARCH John*: Retrieves names matching John as first name or last name.
- SEARCH Miller*: Retrieves names matching Miller as first name or last name.
- SEARCH J*: Retrieves all the contacts matching the letter J.
- SEARCH M*: Retrieves all the contacts matching the letter M.
-

If all these names do not exist in the phonebook then the following error messages will be created and sent:

- SEARCH John: Name not found (* must be used after the name in the query message)
- SEARCH Miller: Name not found (* must be used after the name in the query message)
- SEARCH J: Name not found (* must be used after the name)
- SEARCH M: Name not found (* must be used after the name)

The flow chart representing the project Mobile App is shown in Figure-2.

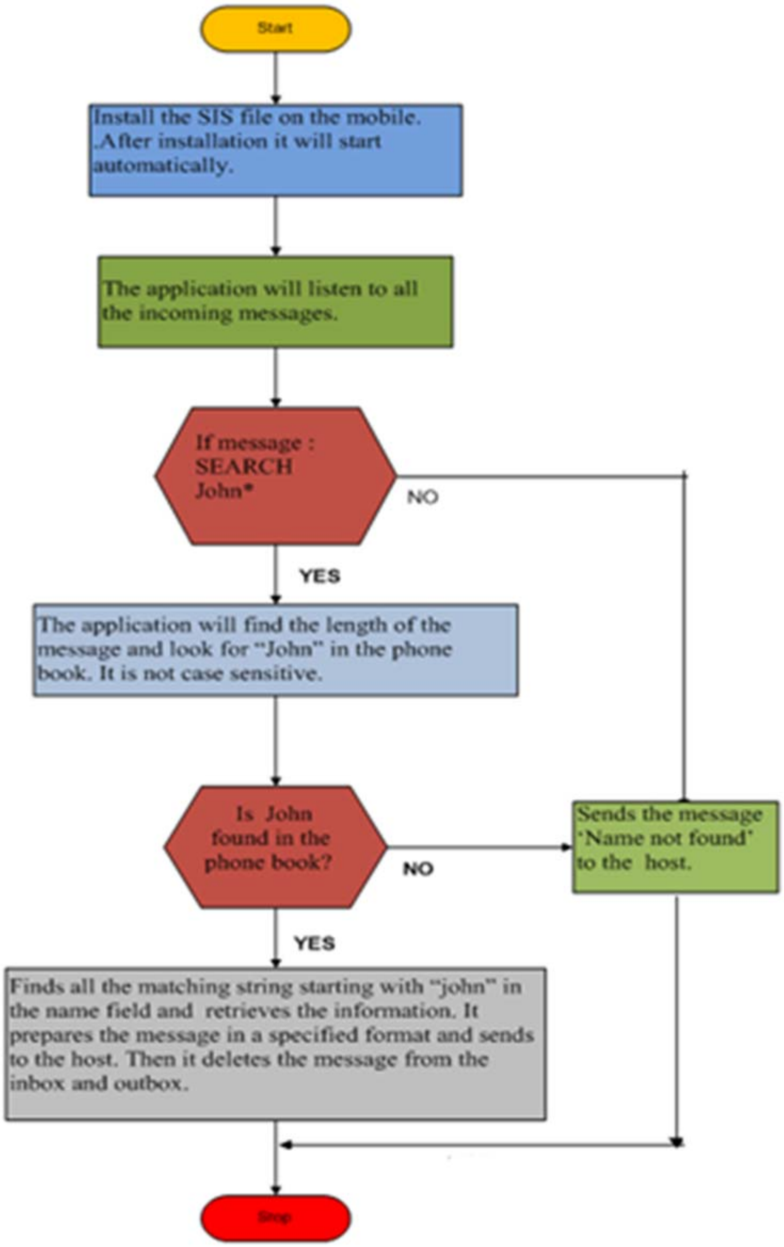

Figure-2: Flow Chart of 'Smart Phone Book Search[12]

Some Examples of the Working Mobile Application System

The process of executing the Symbian OS program using an emulator in a Windows PC is called an emulation. In order to evaluate the executable programs on the hardware, the following software programs were tested using an emulator.

Figure-3: Series 60 emulator screen similar to the mobile phone screen[10]

Running executable files for the Symbian OS on the emulator and debugging them in this environment facilitates coding. If this were done on the mobile phone then debugging and executing would take considerably longer. The series 60 emulator screen (shown in Figure-3) is similar to the mobile phone screen[10]. One can access different folders in the mobile phone except for particular hardware components such as Bluetooth and infrared. These functions, however, can be managed by configuring the emulator.

The series 60 emulator screen has interactive keys[10,12]. The touch sensitive GUI screens help in various input sequences. Hence, all the emulations of Symbian OS programs can be successfully run on a mobile phone after testing.

This Mobile App project was completed in three months with intense, focused learning of the Symbian OS programming language, designing different applications, writing code, testing output and debugging errors[8,9,10]. In this prototype, students applied Agile Program Development techniques and dynamically made design decisions some of which could be improved with additional development time. The following snapshots were taken from this prototype implementation:

1) Figure 4 shows the process of setting and changing the password.
2) Figure 5 shows different search options.
3) Figure 6 shows searching with the wildcard '*'

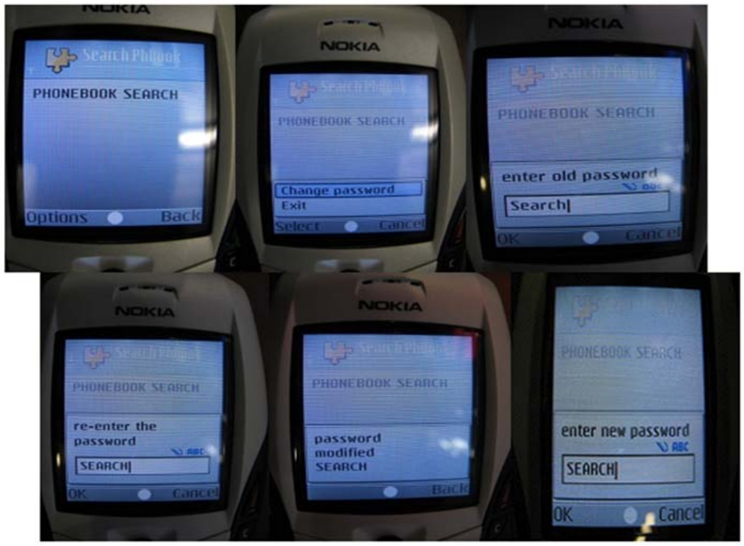

Figure-4: Changing password for security[12]

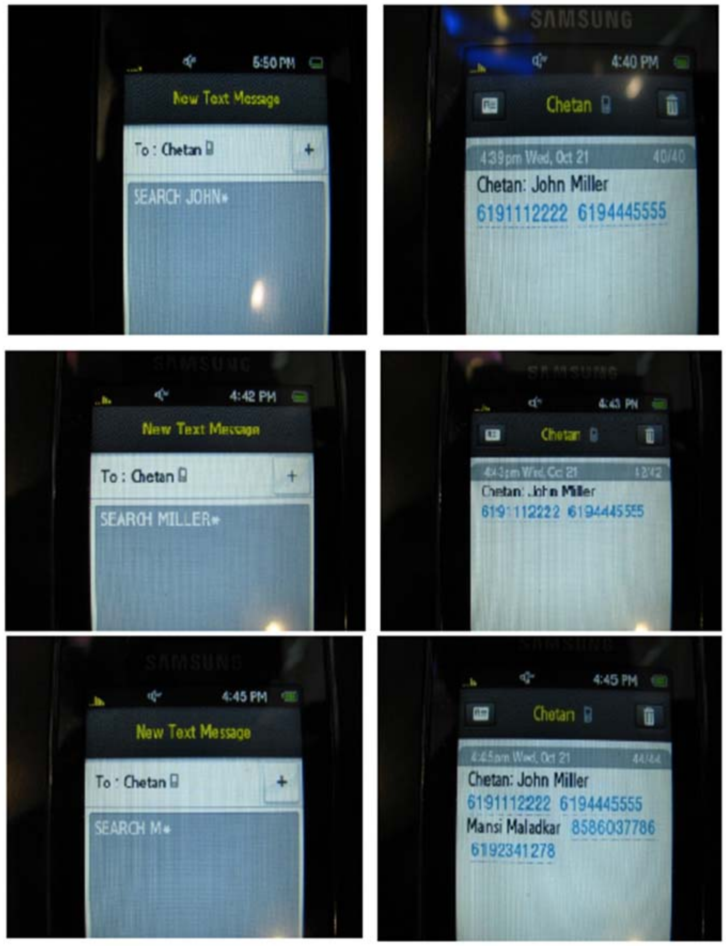

Figure-5: Search Options[12]

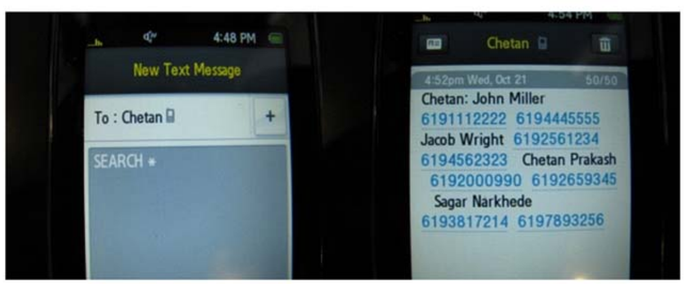

Figure-6: Searching with '*' wild character[12]

Recommendations for Future Research

In an era of exponential growth of wireless technology, the 'Smart Phone Book Search' Mobile App is an exciting innovation that provides a breakthrough technology in mobile application evolution. It integrates the SMS technology with Personal Information Management (PIM). This combination uses SMS technology to communicate between two mobile devices (a server mobile and a client mobile) for retrieving data. This application can be expanded in the future to retrieve multimedia data such as videos, images and other personal information present on the mobile phone. This Mobile App can be made more flexible and reliable in various ways. Currently, the application works only when the mobile server is ON, but it might be possible to make this application work with additional hardware and software when the mobile server is OFF. The application can further be incorporated with the Global Positioning System (GPS) to trace a mobile phone when it is lost or stolen.

Master of Science in Wireless Communication (MSWC) Program at National University

The MSWC program at National University is a new and unique professional curriculum[13]. This program was developed in 2004 based on modern digital communication techniques. It facilitates students in wireless communications to learn problem solving techniques, advanced system design and simulation. The mission of this program is reflected in the program outcomes specified in the university general catalog[13]. In this program, students have the opportunity to learn theory, principles, and hands-on activities in the field through twelve courses. At end of the program, all students are required to take two project classes (Capstone) which allow them to apply technology and solution theories in various new and innovative applications. Most program learning outcomes are achieved in the two project classes: WCM611A and WCM611B. These projects are expected to complete within three months. Figure-7 shows the program mission, program learning outcomes, and project courses with their learning outcomes.

Master of Science in Wireless Communication

The Master of Science in Wireless Communications (MSWC) program is a professional degree that integrates communication techniques, problem solving strategies, simulation skills and mathematical foundations with hands-on training required to solve real world problems in telecommunications. The program is designed for professionals and managers to facilitate the learning and application of skills in the field of wireless communications. The program uses a distinctive and challenging curriculum that emphasizes multidisciplinary knowledge and integrates theory through applications and design concepts.

Program Learning Outcomes

Upon successful completion of this program, students will be able to:

- Evaluate and apply wireless networking, protocols, architectures, and standards to the development and design of wireless communication systems.
- Evaluate and choose the most appropriate kinds of coding and decoding schemes for constructing, detecting and filtering wireless communications signals.
- Build security into wireless communications systems and contrast ethical and related issues in the telecommunications industry.
- Plan, integrate and implement multiple types of Second (2G) and Third Generation (3G) wireless networks.
- Employ strategic analysis software and tools to rapidly, but thoroughly, develop wireless, networks and service plans.
- Develop simulation models of the radio component of wireless systems using MATLAB, SIMULINK and its communication tools, including signal and system representations, filter models, noise generation, Monte Carlo simulation, and post–processing.
- Evaluate and forecast economic impacts of continually advancing technologies on wireless service providers, equipment providers, application providers, and consumers.
- Conduct in-depth research into a specific wireless communication topic, including finding and integrating relevant research results of others.
- Analyze and synthesize wireless communications concepts, project management principles, and ethical standards through graduate-level evaluative and creative written assignments and oral reports.

WCM611A Master's Research Project I

This is the first course of the Master's Research project. It focuses on the selection of an appropriate topic on one area of research or applications in wireless communication systems. Student project teams research the topic of the project and complete the project proposal and timelines for project completions.

Learning Outcomes

Upon successful completion of this course, students will be able to:

- Select project partner(s).
- Distribute the loads and responsibilities among them.
- Setup rules and procedures to accomplish the goal.
- Develop a master level project in Wireless Communication.
- Submit a written project proposal with objectives, methodology, and expected outcomes of the project.
- Obtain an approval of the project.

WCM611B Master's Research Project II

A continuation of WCM 611A. Students complete the project including all required documentation and formally present their final product to a review panel for evaluation. Grading is by H, S, or U only. Course is In Progress (IP) Grade eligible. Two-month course, meets once a week.

Learning Outcomes

Upon successful completion of this course, students will be able to:

- Complete and submit the written project report.
- Demonstrate both written and oral communication skills relevant to a focused research interest.
- Develop the ability of critical and innovative ideas for current and future research areas.
- Identify the needs and importance of the selected research topics for further development.
- Gain sufficient hands-on training as a team member.
- Construct a statistical model for signal analysis in communication area that allows to prove the model, describe the properties and apply in the real world problem.
- Apply the concept of random variable function and the signal sampling techniques for estimation theory.
- Design, implement, and test of wireless communication systems using the spread spectrum transmission and reception, CDMA and GSM principles.
- Integrate the operation and protocols for simplex tone and data paging systems, WAP, WML, WLAN based IEEE 802.11b.
- Utilize the different kinds of coding and decoding schemes used in wireless(Trellies coding, Turbo coding etc.), detection theory concepts: Bayesian approach to statistical inference, hypothesis testing and the Neyman-Pearson lemma, maximum likelihood decision rules, minimax decision rules, composite hypothesis testing, CFAR detection.
- Implement Data Encryption Standard (DES), identification and authentication and public key systems.
- Augment multiuser modulation and demodulation principles including MAI, Chernoff and Bhattacharya bounds, etc.
- Develop the ability of critical thinking and innovative ideas for current and future research in the area of Wireless Communication.

Figure-7: MSWC Program Learning Outcomes and Project Learning Outcome[13]

In this program, students are encouraged and recommended to work as a team to gain valuable experience that is needed by most industries in the 21st Century. In the first month, students form teams (2 to 3 students in a team), select research topics, conduct literature search, analyze critical aspects, and plan to reach a viable solution. In the second and third months, students perform the necessary tests/experiments, data collections, build prototypes, prepare project reports, make formal presentations, and prototype demonstration. All MSWC projects are subject to assessment by a Faculty Judging Panel (two faculty members and two industry professionals) using a "Masters Research Project Assessment" tool that contains all the assessment criteria.

MSWC Program Assessment Criteria and Process

National University is recognized for teaching excellence and values. The MSWC program strives to prepare professionals with the updated knowledge and training in wireless communications. The program reflects evolving and emerging technologies, socio-economic changes, the global economy and other factors. As every program, it is under continual review to maintain high quality and ensure appropriate content. At National University, usually two types of assessment measures are used to evaluate an academic program: 1) direct measures and 2) indirect measures[14]. Every year each program at National University is required to conduct an annual review called the Program Annual Review (PAR) and every five years, a program requires a comprehensive review called the Five-Year Program Review. In addition to these review processes, the MSWC program has an Advisory Board comprised of a few members (7 to 10) primarily from the wireless industry. The Advisory Board meets twice a year and is mainly responsible to evaluate the industry needs, program quality, and relevance.

Validation of Graduate Program and Success

In the 'Smart Phone Book Search' Capstone project, an extensive literature search was conducted by the students in order to identify the critical user requirements, and identify a viable and cost-effective solution. Students completed the project in three months except for the final written version of the report that required additional time for editing and approval. During the first month, four students formed a team based on their common interest, elected a team leader, assigned each member tasks and responsibilities, and collected the required materials and equipment/resources. During the last two months, students were engaged in accomplishing the following: 1) design and development of different software using the appropriate tools and platforms, 2) integration of hardware and software for building a prototype, 3) testing and evaluation of the prototype, 4) collection of data and information, 5) organizing ideas and thoughts, and 6) preparing for the presentation and the first draft of the written project report. At the end of the third month, students submitted their project report (first draft) to the Faculty Judging Panel for review and made a formal presentation followed by a successful demonstration.

After observation of this project presentation and careful review of the written report Panel Members submitted their evaluation reports to the MSWC Program Lead Faculty. The summary of these evaluations and rubrics used for this project are displayed in the Figures- 8 & 9. All these evaluations and valuable comments received from the Faculty Judging Panel indicate that students did very well in the project, gained appropriate graduate level knowledge and practical experience in the field. The findings of this study further confirm that student learning is aligned with the program missions and program learning outcomes.

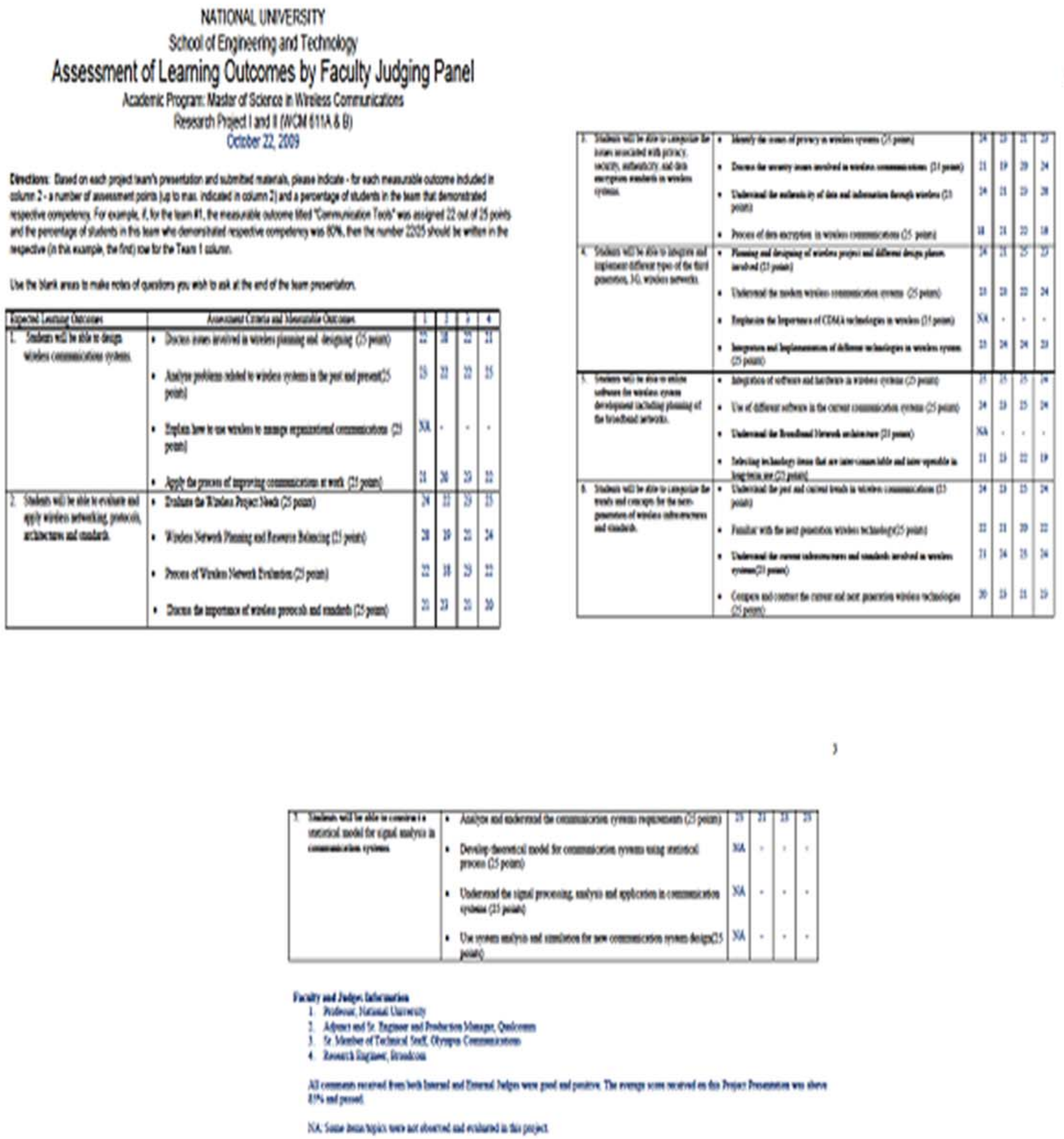

Figure-8: Average Score Received on Project Presentation[13]

NATIONAL UNIVERSITY
School of Engineering and Technology
Master of Science in Wireless Communications

WCM 611 WRITTEN PROJECT EVALUATION FORM

REPORT TITLE: SMART PHONE BOOK SEARCH

AUTHOR(S): Student 1, Student 2, and Student 3

Date of Evaluation: January 15, 2010

Rubrics for Written Report Evaluations

AREA	OUTSTANDING 9-10 points	GOOD 7.5-8.999 points	FAIR 6-7.499 points	POOR < 6 points
FACTS	The student provided expert information relevant to the topic. The detail and scope of the information incorporated into the project demonstrates exceptional familiarity with the topic.	The student provided accurate information relevant to the topic. The student could have provided greater detail and scope. The detail and scope of the information incorporated into the project demonstrates considerable familiarity with the topic.	The student had some difficulty furnishing sufficient evidence. The detail and scope of the information incorporated into the project demonstrates limited familiarity with the topic.	The student failed to provide information that is accurate and relevant to the project. The detail and scope of the information incorporated into the project was insufficient.
ANALYSIS	The student analyzed the question / problem / thesis from all relevant perspectives. Facts, key concepts and principles were presented in an orderly fashion. Inferences were logically sound and conclusions were well supported.	The student analyzed the question / problem / thesis from multiple perspectives. The student's presentation of facts, and principles was orderly, with one erroneous inference.	The student analysis of the question / problem / thesis was limited. Some of the facts, are presented in a disorderly fashion with some erroneous inferences.	The student failed to analyze the question / problem / thesis. Presentation of facts, key concepts and principles is disorderly and there are multiple errors in reasoning.
SYNTHESIS	The student combined ideas in novel ways around an imaginative central concept to create a novel, impactful, coherent essay/solution. In addition, the student placed the topic in a new context and/or made important new connections to other events, people, places and things.	The student brought together ideas around a central concept to create a meaningful, coherent essay/solution. In addition, the student placed the topic in an appropriate context and/or made relevant connections to other events, people, places and things.	The student brought together ideas around a central concept, however, sufficient context is lacking. The essay/solution contains satisfactory factual and conceptual content, but is presented in a disjointed, "grocery list" fashion.	The student has failed to construct a coherent essay/solution built around an identifiable organizing theme or concept.
RESEARCH	The student has used a wide variety of informative and relevant appropriate professional sources, and integrated them seamlessly into the body of the project. Conclusions are verified or verifiability has been incorporated.	The student has used a sufficient number of informative and relevant appropriate primary professional sources. Conclusions are logical	The student has provided sources but had difficulty integrating them. Conclusions are incomplete, questionable, or difficult to discern.	The student has failed to provide sufficient relevant sources for this assignment and/or failed to adequately incorporate outside sources into the body of the project. Conclusions are missing, irrelevant or unacceptable
VOCABULARY, MECHANICS & SENTENCE STRUCTURE	The student has combined the effective use of subject-specific terminology with extensive vocabulary and variety of expression. The student consistently uses correct grammar, syntax, spelling, punctuation, and capitalization.	The student has demonstrated good use of vocabulary and variety of expression The student has an average of fewer than 3 errors per page in grammar, syntax, spelling, punctuation, and capitalization..	The student has demonstrated limited vocabulary or variety of expression. The student has an average of 3 or 4 errors per page in grammar, syntax, spelling, punctuation, and capitalization.	The student has utilized a vocabulary with little or no range and/or no variety in expression. The student has an average of more than 4 errors per page in grammar, syntax, spelling, punctuation, and capitalization.
FORM	The report follows APA format. The student has organized ideas into coherent paragraphs with smooth transitions. The assignment has good structure and unity.	The report follows APA format. Transitions are sometimes awkward, and/or the assignment does not always hold together.	The report deviates from APA format in a number of areas. There is weakness in one of the following criteria: organized paragraphs or smooth transitions.	The report does not follow APA format. The student has not demonstrated an understanding of paragraph structure, transitions, or unity. Student has not adhered to NU Capstone/Masters Research Project guidelines.

AREA	SCORE (out of 10 points)				
	FT1	PT1	EJ1	EJ2	Avg.
1. FACTS	9	8	9	10	9.0
2. ANALYSIS	9	8	10	9	9.0
3. SYNTHESIS	8	9	8	9	8.5
4. RESEARCH	9	10	10	9	9.5
5. VOCABULARY, MECHANICS, ETC.	7	8	6	7	7.0
6. FORM	8	9	8	9	8.5
7. TOTAL SCORE (Maximum – 60 points)	49	51	49	49	51.5 (85.83%)

In the light of your professional experience, does the report show mastery of the topic at a Master's level for the following facets?

- Sufficient original work (for a 2-month project): Work is found to be original
- Accurate representation of basic technical concepts: Concepts used in this work are appropriate
- Intelligent discussion of results (rather than just mentioning them): Results and discussions are meaningful
- Adequate depth and variety of analysis: Data analysis and interpretation are accurate

Other Comments (add additional pages if needed): Overall quality of work is good and valuable

FT1: FT Faculty 1, Professor, National University
PT1: NU PT Faculty and FT Qualcomm Sr. Engineering and Production Manager
EJ1: External Judge 1, Sr. Member of Technical Staff, Olympus Communications
EJ2: External Judge 2, Research Engineer, Broadcom

PS: Both External Judges have no prior relationships with the Program and National University
The average score received on this Project Report was above 85% and passed.

Figure-9: Average Score Received on Written Project Report[13]

Concluding Remarks

The 'Smart Phone Book Search' application represents the new era of technology focused on enhancing mobile phone features. It provides a unique solution to any user who wishes to have constant access to the contact information stored on his/her mobile phone. It employs the popular SMS feature that is available on most mobile phones. The password feature used in this project makes the application secure. It ensures the user with a valid password to retrieve the contact detail. Further, there is also a provision to change the password for security. This new application is developed using Symbian C++ code to work on the Symbian OS version 7.0 platform which runs on Nokia 6600 mobile phone. This enhances the effective data transfer through SMS messages. At the present time, this Mobile App is capable of retrieving text data for both single and multiple contact information. Under normal network conditions, the process of retrieving contact information is fast (15 sec). The 'Smart Phone Book Search' application integrates the SMS facility with Personal Information Management (PIM) for retrieving data from a remotely located mobile phone.

The 'Smart Phone Book Search' is not only a technological achievement, but a responsible attempt to serve mobile users. This is a new Mobile App developed by MSWC students at National University. As of today, these authors have not found any system similar to the 'Smart Phone Book Search' anywhere. Hence, it is considered a technological innovation. This system combines the advanced knowledge of wireless communication, and computer science. This report confirms that the student project, 'Smart Phone Book Search', met the program's requirements and fulfilled the program's mission. In these project classes, students received high scores from the Faculty Judging Panel and passed. All this evidence clearly indicates that the research project is appropriate for a graduate program, and the students' learning from the project classes reflects the program mission and program learning outcomes.

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Developing a Low Cost Prosthetic Foot for the Vida Nueva Clinic: A Multidisciplinary Senior Design Project

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Abstract

In Spring 2010, five Cal Poly students joined to form the Piernas de Vida senior project team. Our intention was to address the growing need for low-cost prostheses in developing countries. In conjunction with Matt Robinson, a local prosthetist, and Vida Nueva, a Honduran prosthesis clinic, we are designing components that are made from materials found locally and that can be manufactured in house. We are currently developing a foot/ankle system, and will be implementing the M1 knee (designed by LeTourneau University) in conjunction with our design. Additionally, we are investigating methods using recycled PET plastic bottles that are commonly thrown to waste as the material for our foot design. In order to effectively implement our design, we have developed a business model to extend the use of our product beyond Vida Nueva to the rest of Central and South America. In order to sustain the project over several years, we are looking to Engineering World Health, a club on campus that is focused on improving public health through engineering. This partnership offers students design opportunities and provides the Piernas de Vida team with continuing student support. Through this project, Cal Poly has the opportunity to impact hundreds of amputee patients throughout Central and South America while providing a strong educational experience for engineering students.

Introduction

At a Spring 2010 meeting for the student chapter of Engineering World Health, a local prosthetist in San Luis Obispo presented the idea of designing low-cost prostheses for clinics in developing countries. Mr. Matt Robinson outlined the need for such a product and expressed enthusiasm in forming a student team to undertake this service-learning project. Several members of our team were interested in the opportunity and presented the idea to the Cal Poly Mechanical Engineering department and the concept was approved as a senior project for the 2010-2011 academic year. The team became a multidisciplinary effort involving not only mechanical engineering but materials and biomedical engineering as well. We have since built a relationship with Vida Nueva, a prosthesis and orthosis clinic in Choluteca, Honduras. Our interaction with this clinic has further increased our understanding of the need, which has provided a solid foundation for our design.

Background

Walking is such a part of everyday life in the developing world that it is frequently taken for granted. Transportation is often limited, and it is not uncommon for people to walk several miles every day to get to and from work, the grocery store, etc. A growing number of people, however, have severe disabilities due to traumatic, dysvascular, and congenital defects. There are 300,000-400,000 known landmine-related amputees worldwide, of whom 20% are children. In total, it is estimated that there are up to 500,000 total amputees worldwide, and that 5,000-10,000 are added to this number each year.[1] Furthermore, the World Health Organization estimates that approximately two-thirds of people with disabilities live in rural areas and may not have proper access to rehabilitative care. The ability to receive a prosthesis can affect the livelihood of an entire family. Many of the amputees in Honduras are working men that were injured in mine explosions or train accidents. These men are often the main provider for the family and after an amputation they lose work because they are unable to perform the tasks required for their jobs. Therefore, a prosthetic leg that can allow them to earn a living is critical. In addition to empowering individuals to continue working, a well-designed prosthetic leg can improve a patient's self-image. Dealing with persons with physical impairments in any culture can be uncomfortable for both the patient and those interacting with the patient. There are many cultural stigmas attached with those who have disabilities, including viewing them as inferior and incapable. Piernas de Vida hopes to fight back against stigmas held against persons with physical impairments and design products that can help break social and cultural barriers.

The Vida Nueva Clinic

Many clinics and organizations have been established in the developing world to attempt to treat those with lower limb impairments. One success story is the Vida Nueva clinic in Choluteca, Honduras, seen in Figure 1. Since it opened in 2003, the clinic has provided 369 new prostheses, 1278 orthoses, and performed 521 repairs. The clinic treats approximately 70 patients per year, including both children and adults. Vida Nueva prides itself on providing prostheses to patients who normally cannot pay. They also maintain close relationships with their patients to ensure proper fit and to provide follow-up care. However, because Vida Nueva is funded entirely by international aid organizations and other private donations, the clinic typically has to turn away 10-20 people per year because they do not have funds for the necessary components.

Figure 1: Front of Vida Nueva Prosthesis Clinic

Currently Vida Nueva purchases most of its hardware from the US or Switzerland. Their typical costs are $550 for an above knee and $350 for a below knee prosthesis. Considering that the estimated per capita gross domestic product is $1829, the cost for these prostheses is beyond the reach of most Hondurans.[2] If Vida Nueva could manufacture high quality, lower cost prostheses within the country it could potentially help them to serve a larger population base as well as spur on the local economy by allowing individuals with disabilities to return to the workforce.

Needs Assessment Trip


Figure 2: Reina Estrada, director of Vida Nueva

One of our team members visited the clinic during the summer 2010 and established a relationship with Reina Estrada, the Director of Vida Nueva pictured in Figure 2. In October, the entire team took a weekend trip to the clinic to perform a needs assessment and further develop relationships with the technicians (prosthetists), Walter and Roque, as well as several of the clinic's patients. We spent two days in the clinic and during this time had the opportunity to interview several patients who were receiving new prostheses or were in for regular adjustments. From these interviews we learned more about their stories and better understood their specific needs. We also observed Walter and Roque at work fitting patients with prostheses and discussed their thoughts about problems with the current designs. This trip was instrumental for both parties involved because it provided inspiration and enthusiasm. Our teammate, Kevin, said that "Our trip to Honduras showed [him] how fortunate we are to have grown up in a country with bountiful resources" and he "left Honduras with a feeling of responsibility to use the knowledge [he] has gained in school to help others." Also, the trip provided the information about the needs, technical abilities, and available supplies at Vida Nueva that would have been extremely hard to attain otherwise.

The Piernas de Vida Team

The Piernas de Vida senior project team is a multidisciplinary group consisting of Sarah Baker (MATE), Justin Lekos, (ME), Adam Paicely (ME), Jennifer Van Donk (ME), and Kevin Yamauchi (ME). The project is advised by Dr. Brian Self from the Mechanical Engineering Department. We specifically chose an interdisciplinary group in order to better model real world working experiences and benefit from differing skill sets. Sarah commented that working on a multidisciplinary team has taught her "what [her] weaknesses and strengths are as well as what makes a materials engineer different from other disciplines." Justin also felt that he has experienced many challenges by working with an interdisciplinary team, but feels that after working through the hardships our team has "arisen as a more effective and streamlined entity, with the specialties and strengths of each person being recognized and effectively utilized." Those specialties and strengths he mentioned vary greatly and include: excellent design and solid modeling skills, strong knowledge of materials, networking and communication skills, and especially important for this project, a strong grasp of the Spanish language.

The final key member of our local stateside team is Matt Robinson. He provides our team with significant information about what is currently used in industry and has good insights into the viability of our designs. Mr. Robinson also has several patients who are willing to test our designs. This will provide crucial feedback that will help us optimize our design. Having this industry partnership as well as the influence of a variety of engineering disciplines are key factors in both our learning as a team and the ultimate success of our product.

Experiential Learning

As mentioned above, this project became a part of the Mechanical Engineering senior project series. Mechanical Engineering students at Cal Poly participate in a year-long design project of their choice that serves as a capstone to their education. The students have the option of participating in a variety of projects that may be sponsored by industry professionals or tailored specifically by the students themselves. During this nine month project students identify a need, brainstorm solutions, design a final concept, then build, test, and implement their design. Adam said that through this process he has learned "that there are many barriers that must be overcome in an engineering project… you can come up with a solution that works, but other factors prevent it from being a good solution such as cost, cultural norms, complexity, manufacturability, and ergonomics." Another exciting aspect of the project is that most teams design products for a particular customer, and successful projects are often used by this customer immediately. The direct customer involvement provides students with great motivation to produce the best products possible. Throughout the process students are encouraged to consider these specific course learning outcomes:

1. Apply a formal engineering design process to solve an open-ended, externally supplied engineering design problem.
2. Work effectively on an engineering team.
3. Formally define an engineering problem and generate an engineering specification document.
4. Apply creative techniques to generate conceptual design solutions.
5. Apply structured decision schemes to select appropriate engineering concepts in a team environment.
6. Evaluate potential design solutions through the use of engineering and physical science analysis techniques and tools.
7. Construct and test prototype designs.
8. Develop and implement a design verification plan and report.
9. Communicate and present engineering design project results orally, graphically and in writing.
10. Discuss engineering professionalism and its responsibility to society.

In addition to the learning objectives above, we have written the following objectives for the Piernas de Vida team:

1. Develop an understanding of the cultural and social difficulties that may be faced by people with disabilities, particularly in a foreign country.
2. Appreciate the cultural differences that are encountered in Central America.
3. Gain an appreciation for the societal role of engineers.
4. Understand sustainable engineering.
5. Develop lasting business practices to support local economies.

An additional optional aspect to several of these projects, including ours, is a business model to support the design. This added component challenges students to think about how to market their design and establish a functioning business. The Piernas de Vida project takes this idea one step further and introduces the aspect of working with a non-profit organization in a foreign country. This means that students are forced to think about a global market and are working with extremely low-income prosthesis clinics that rely almost entirely on foreign aid. Through this entire experience students apply their coursework in real life applications and come away with valuable engineering application skills.

The Design

During this first year of design, Piernas de Vida has begun to develop a prosthesis comprised of a layer foot with a simple bolt ankle, ankle adapter, a LeTourneau M1 knee[2], and a standard pylon.

The Layer Foot

The layer foot, pictured in Figure 3, is composed of multiple layers of material fastened with a bolt that simultaneously acts as the ankle. The layered design will allow for controlled flexion, and by joining the layers at different locations could provide a variety of gait responses. This also gives clinicians control over the foot behavior and allows them to vary the response according to individual patient needs.

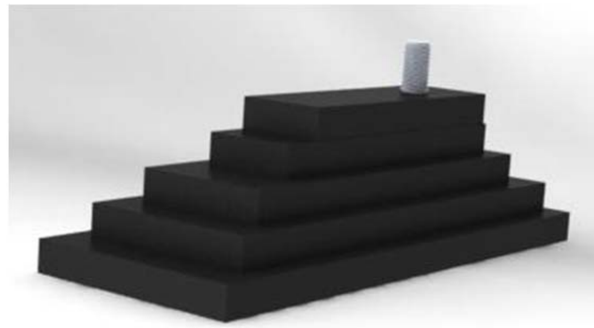

Figure 3: Solid model of layer foot

Ideally, we would like to use polyethylene terephthalate (PET) recycled from plastic bottles to form the layers. We noticed piles of bottles virtually everywhere in of Honduras, so we know that it is a prevalent material and available at fairly low costs. However, the plastic must be melted into sheets, and this alone presents significant challenges. This process is described in more detail below.

In the event that the recycling process is too complex, we have also researched the viability of using polyoxymethylene (Delrin). This material is an ideal alternative because it shares similar material properties to PET and is the same material used in the LeTourneau M1 knee.[2] The greatest downside to Delrin is that it is not available in-country; however the layer foot would fulfill our low cost requirement with either material. Similar to PET, Delrin is easy to work with. While we do not have the full fabrication process defined, we have constructed a prototype using only a jig saw, drill press, and basic hardware such as clamps and hammers. Technicians should have little trouble learning how to fabricate the foot and the clinic will not have to purchase many large pieces of equipment for them to do so.

The clinic has also expressed interest in a cosmetic cover, and we intend to incorporate one into our design. We are still unsure whether standard cosmetic covers will fit the layer foot, but if they do not a new less expensive cover will become a part of future design iterations.

Adapter

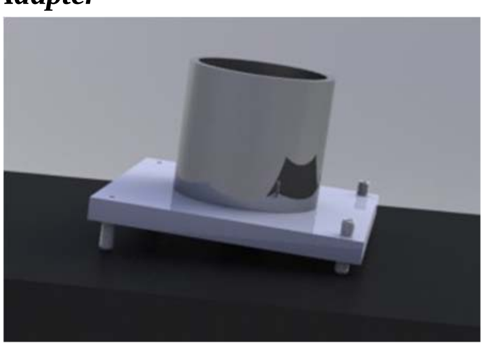

Figure 4: Solid model of ankle adapter. Image displays two of the three critical components, including the pylon cup and set screws. Component not seen is the spherical washer.

The final design will also incorporate an ankle adapter to connect the foot to the pylon. The ankle adapter is crucial in the adjustment of a prosthesis, and an ideal adjustment mechanism would have continuous adjustment in four different degrees of motion. As seen in Figure 4, our current design uses a cup to fit around the pylon welded to a square plate that is adjusted using four set screws. The bolt from the foot runs

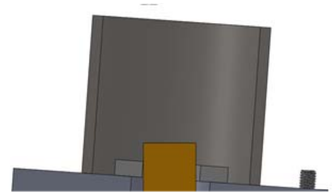

Figure 5: Section view of ankle adapter. View shows bolt coming up through adapter. Image does not show the nuts that will hold the adapter in place after adjustment.

up through the center of the fixture, and a set of spherical washers located on top and bottom of the square plate allow the foot to rotate while still providing enough contact to hold the fixture in place. In Figure 5 the two small washers represent the spherical washers to be used, and an additional nut will be located at the top of the bolt, picture there as the brown rod coming up through the center of the fixture. The four set screws will hold the angle of the fixture while the technician makes adjustments. After the adapter is set into its final position the technician will tighten down a nut at the top of the assembly to hold it fixed in place. The set screws are ideal because they offer the technician continuous adjustment in flexion/extension and inversion/eversion. It is a fairly simple design with standard components so technicians can easily assemble them.

Knee

Through a process of brainstorming and comparing designs, the Piernas de Vida team decided that the Le Tourneau M1 knee[2], Figure 6, fits all our specifications and our design efforts would be better served elsewhere. The biggest foci of the project as mentioned are cost and manufacturability. The M1 knee has been specifically developed for low-income countries and therefore fits both of these standards. The manufacturing requires only basic machining equipment to form squares, drill basic holes, and shape several rounded linkages. All of these things could potentially be done with a band saw and drill press if the technician is skilled. Furthermore, Le Tourneau has established a means of implementing their designs into clinics and we are in a great position to learn from their process.

Figure 4: Le Tourneau M1 knee[2]

Pylon

The pylon will be a standard prosthesis pylon, a 30mm stainless steel tube.

Recyled PET

Ideally, we would use recycled plastic bottles to create the layers for our layered feet. The challenge, though, is creating sheets of PET from a collection of bottles. Sarah, our Materials Engineering team member, is working hard on understanding the process of recycling bottles into useable material. She said that her time in the lab researching the materials is a huge learning experience. "Seeking assistance from professors can be helpful at times, but seeing the effects of compression molding or extrusion on Polyethylene Terephthalate is the ultimate learning experience." Prepared PET pieces from one of our trial experiments are shown in Figure 7. These pieces were cut from used plastic bottles and melted in a furnace. The resulting plastic was unusable and the results of this test spurred us to search for better recycling options.

Figure 5: Cut plastic bottles prepared for the first recycling pilot experiment.

We have discussed several viable options including compression molding (where plastic flakes are placed into a mold and compressed at high heat and high pressure into a flat sheet) and extruding (where flakes are placed into a machine that heats them and then compresses them out through a rectangular die to form films). The challenging task now is to create these processes on a scale that can be replicated at clinics throughout the developing world. This aspect of the project will likely be a large focus of the team in the coming year and we hope it will result in a low- cost method for recycling the PET into sheets. Our collaborators Dennis Sabourin, of The National Association for PET Container Resources, and Keith Vorst, a Cal Poly Industrial Technology professor and recycling entrepreneur, can provide critical insight to developing proper recycling procedures.

Testing

A critical element in proving the strength of our design is rigorous testing following both the International Organization for Standardization standards outlined in ISO 22675 and the Roll-over Shape testing described by Hansen et all.[3] The testing described by the International Organization for Standardization will ensure that our components meet the strength requirements These tests include static proof, static ultimate strength, and cyclic testing on each component. We will build several prototypes of our components to optimize the design and perform testing on each prototype. The Roll-over Shape testing compares the gait response of our foot to the response of a natural foot as well as to other prosthetic feet on the market. These tests will provide insight to whether the gait produced by our foot is comfortable and natural. The Roll-over Shape tests require a Prosthetic Foot Loading Apparatus, Figure 9, which is a mechanical test fixture designed specifically to apply loading at varying angles to prosthetic feet. At each angle we can determine the center of pressure on the base of the foot and model how the force will transmit over the foot during different phases of gait. In doing the analysis for our layer foot we mathematically calculated the center of pressure for our design and produced the graph seen in Figure 8.

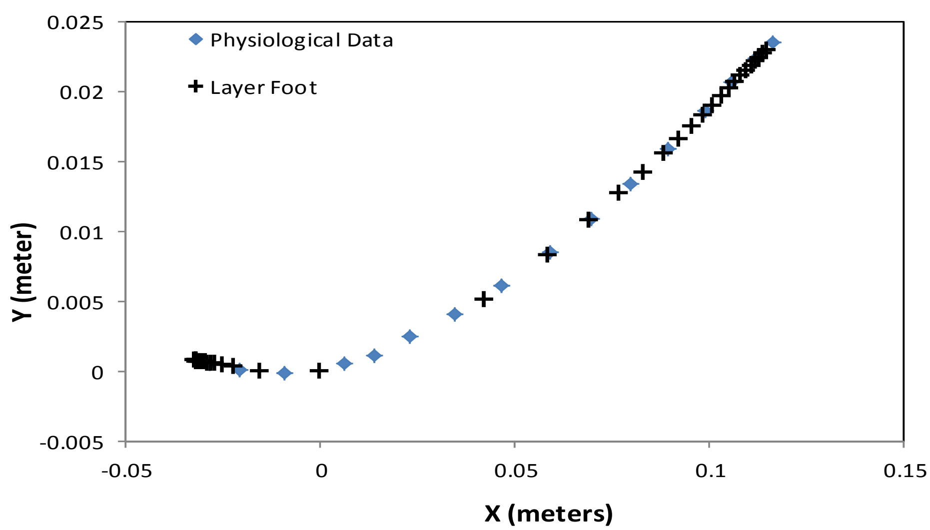

Figure 6: The roll-over shape produced from computer-simulated DRA compared with actual physiological data.

As you can see from the graph the predicted rollover shape for our design theoretically matches very closely with a human gait. In order to prove the validity of this model, though, we must gather experimental data and compare it to our theoretical model. We plan to construct the Prosthetic Foot Loading Apparatus at the beginning of the upcoming quarter and perform testing on a minimum of 5-10 prototypes. This test fixture will then be available for future teams to analyze their designs as well.

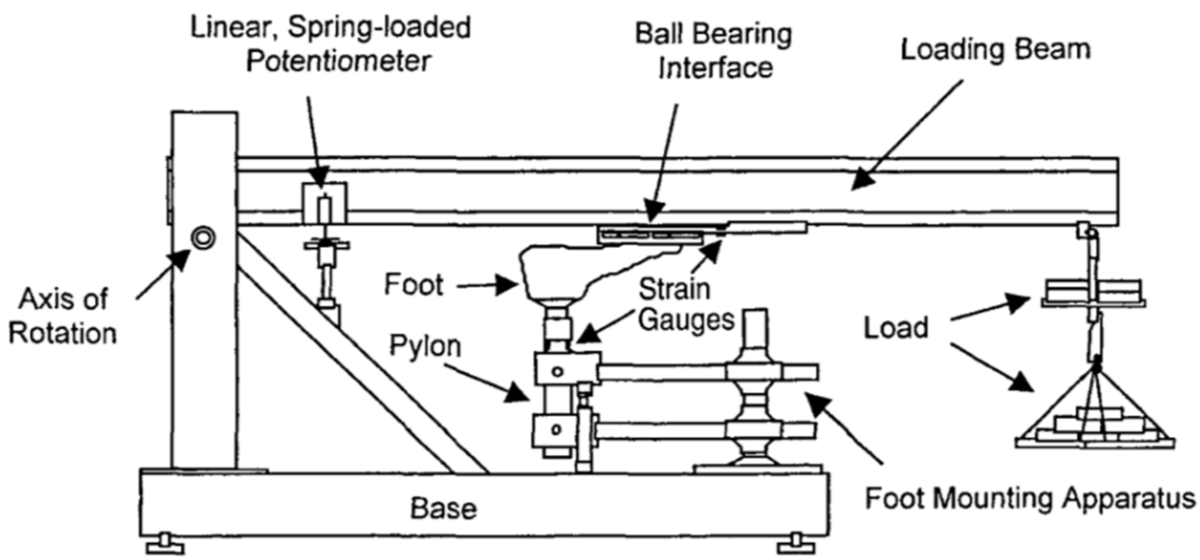

Figure 7: Prosthetic Foot Loading Device as described by Hansen et all.[3]

Implementation

Nearly as critical as the design process is the implementation of the design. Jen said one of the biggest things she has learned is that "a great idea must be well thought out and presented in a way that will allow it to succeed." As engineering students we are not typically asked to generate business models for our designs so we were forced to think beyond just the numbers of the analysis. We had to generate a sound business model to spread our design. The following flow chart (Figure 10) shows three viable plans to implement the foot design in new clinics throughout Central America.

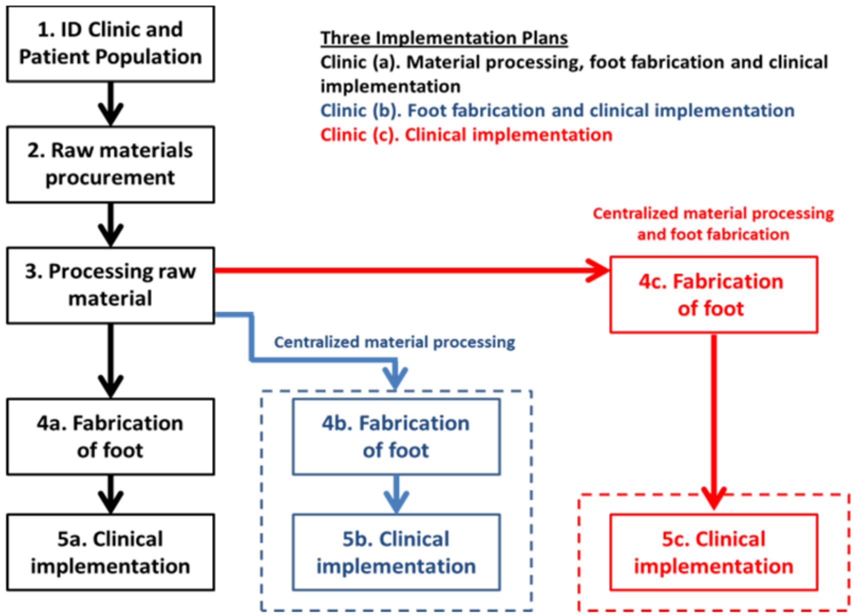

Figure 8: Flowchart of procedure to implement the foot design into new clinics.

1. **Clinic Need**
   For each new clinic we must determine the need and patient base before we implement the new design.

2. **Material Procurement**
   We plan to use recycled PET obtained from bottles in the local community. If this material proves to be feasible, the clinics will need a viable collection system for plastic bottles. Based on a rough density comparison, twenty-four bottles can be recycled into approximately 1.09 pounds of reusable PET. Based on rough initial calculations, each foot would require between 15 and 40 bottles, depending on the final weight of the foot. We have developed four different means to collect the bottles:

a. **Patient Collection**: Requires that each patient bring a given number of bottles to the clinic for their foot. This model allows the patients to be involved and to contribute to their foot, but it is limited by each patient's accessibility to used plastic bottles.
b. **Community Donation**: Involves collection centers at local churches, businesses, or community service organizations. This process is limited by the interest of the community to both provide the collection centers and of citizens to use the bins to dispose of their used bottles.
c. **Community Purchase**: Similar to Community Donation this method depends on collection centers, however the clinic would pay for the collection services to provide added incentive for participation.
d. **Reclaimer Purchase:** Vida Nueva would purchase sheets of pre-processed plastic from a near-by reclaimer. The largest issue with this is that the closest reclaimer is located in Mexico.

3. **Processing Raw Material**
   Table 1 outlines the steps for processing PET bottles into a useable sheet of plastic as well as the costs of the equipment necessary for the process.

Table 1: Process to prepare PET from bottle to sheet for use in layer foot

Step	Process
1	Remove glue and debris from bottles and clean with a mild chemical cleaner
2	Grind bottles into small flakes
3	Dry flakes
4	Create sheets of PET

Step 4 can potentially be accomplished by either an extruder or a compression mold, as mentioned above, both of which are fairly expensive. In our initial clinic, Vida Nueva, we plan to either purchase or find donated equipment. During the 2011-2012 academic year we plan to have another senior project team design a low cost extruder or compression mold that a small clinic can purchase or build themselves.

4. Fabrication of foot

a. Decentralized clinical fabrication:

This method provides each clinic with all the tooling and machinery needed to fabricate the foot within the clinic. Each clinic provides only the feet needed within their clinic, or possibly assists one or two clinics nearby.

b. Centralized raw material processing

One centrally located clinic or plant processes the plastics into sheets of raw material and ships it to multiple clinics. Each clinic then fabricates feet for their patients.

c. Centralized foot fabrication

One centrally located clinic or plant processes the plastics into sheets of raw PET material then fabricates the feet to send to clinics in the surrounding areas. Each clinic then fits the pre-manufactured feet to their patients.

5. Clinical Implementation

Whether the foot is processed and fabricated in a centralized or decentralized location, the implementation is the same. Technicians from each clinic, like Walter from Vida Nueva (seen in Figure 11), will select the appropriate size foot for their patient and fit the patient with a similar methodology to what is currently used.

Figure 9: Vida Nueva technician Walter with director Reina in front of their clinic.

The overall impact of this project will likely start small, with approximately 20-30 patients per clinic receiving the new prosthesis, but as the design proves to be viable, it could replace their existing products. During the first three years of the project we will likely serve 100-150 patients at four different clinics, but this will exponentially increase with every new clinic and their increased use of the new design. At the end of five years we hope to have at least six clinics using the new technology and roughly 300-400 patients using our prostheses. There are currently up to 500,000 amputees worldwide. With such a large population of users the demand is high and the likelihood of substantial impact is great.

Instructor Perspective

Dr. Brian Self has been working with our team from the beginning and he said, "It has been interesting to watch this multidisciplinary team grow and learn to work together. They have gathered input from their sponsors in Honduras, mechanical, industrial, and materials engineering professors, as well as our local prosthetist. They have been very proactive, and located and largely wrote the grant to the National Collegiate Inventors and Innovators Alliance."

He also commented about how the school is assessing service learning projects. Currently they have several means to evaluate how the students are learning. All senior project students, including those working on more traditional industry-based senior projects, are completing two reflections each quarter. Additional assessment tools include the Engineering Design Self-Efficacy Instrument[4] Situational Motivation Scale (SIMS)[5] the Abelism Index, and focus groups. Results from these assessments should be available in the Fall of 2011.

Conclusion

Ultimately, as mentioned above, the goal of the capstone project is to use all the material we have learned from our four years of undergraduate work in a real world design situation and learn how to practically apply our engineering skills. Our journey through this process has been an incredible learning experience for every member of the team. We have overcome many obstacles in dealing with international relations, working with the challenges of a multidisciplinary team, and setting expectations too high for what can be reasonably accomplished in one year. As a team we have commented that we have a lot of knowledge now that we wish we had at the beginning so we could be a more effective team. With respect to the final deliverables, we certainly have not achieved our initial goals, and likely will not accomplish everything we set out to do in this year. It is disappointing to discover that we cannot save the world in nine months; however from a learning perspective we recognize that we have gained skills and experience that will be invaluable as we enter the workforce.

Our realization that we could not finish the project this year also spurred us to develop means for it to continue in the years to come. We have laid a good ground work for a very successful product, and future teams may improve on our design with further iterations and develop improved business models. To continue funding our work we applied for a grant from National Collegiate Inventors and Innovators Alliance (an additional learning experience). We unfortunately did not receive funding this year, however they had a very positive response to our proposal and we anticipate receiving funds next year after the project has developed further. Also, the team is actively involved with the Cal Poly student chapter of Engineering World Health. Many of the students involved in the club have expressed great interest in prosthesis design, and this momentum will contribute to the success of the project in future years. We hope to fill next year's senior design project team with Engineering World Health club members and thereby sustain our relationship with Vida Nueva. In order to generate interest we have begun a test design of an ankle adapter designed by a technician in Bolivia. Matt Pepe of the Rotary Clinic in La Paz, Bolivia has created an adapter that works well in his clinic, but he does not have the means or expertise to perform testing on the piece. We currently have four students working on this design. With the support of Engineering World Health, the project can develop into a sustainable venture and extend to other small private clinics within Honduras and eventually other low-income countries.

Despite the setback we have seen, the Piernas de Vida team has been working hard to improve the types of prostheses available in developing countries, and we are enthusiastic about our design. We have come a long way since we started just under a year ago, and we believe that through the continuation of the Engineering World Health club and ongoing senior projects we can have a huge impact in the global community.

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The Piernas de Vida team has received considerable support for the project from within and outside the Cal Poly community. We appreciate Boeing for a grant providing funds to travel and procure materials. The project has also been funded through an NSF Research to Aid Persons with Disabilities (RAPD) Grant (award #0756210, Access by Design: Capstone Projects to Promote Adapted Physical Activity). Thank you to the various professors at Cal Poly for their advice and assistance including Dr. Mello and Dr. Vorst, and to those in industry who have given us advice on the PET recycling process.

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Implementation of Particle Image Velocimetry in the Fluid Mechanics Laboratory

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Abstract

The study of fluid mechanics is essential to many industrial and commercial applications. Examples include irrigation, sewer collection, water distribution, piping, heating, ventilation and air conditioning systems, aerodynamics, and power generation. Therefore, it is necessary that students have a good understanding of the concepts behind these and other applications. For this reason, the Civil and Mechanical Engineering programs at the College of Engineering at California State University-Los Angeles have two related courses in their curriculum: a theory course named CE/ME 303 Fluid Mechanics I and a corresponding laboratory course named CE/ME 313 Fluid Mechanics Laboratory I. Although the theoretical course has been developed to solve certain types of real-life problems involving fluids, unless one observes what they are, the knowledge is abstract. For this reason the Fluid Mechanics laboratory CE/ME 313, introduces the students through hands-on experiments, to several mechanisms seen in the theory course. Recently, the college of engineering through collaboration between its Center for Energy and Sustainability and Interactive Flow Studies Corporation acquired two educational interactive flow visualization systems, namely FLOWCOACH and ePIV. Flow visualization with these systems provides an excellent opportunity for visual appreciation of the complexity of flow phenomena. Visualization experiments can be used to enhance the learning experience and improve understanding on the following concepts: (i) streamlines, pathlines, timelines and streaklines; (ii) laminar and turbulent flow regimes on a flat plate; (iii) boundary layer development and its associated shear stresses, vorticity and the velocity field; (iv) separation of flows past an object; (v) laminar flow over slender bodies, airfoils, or cylinders; and (vi) the development of vortices behind a moving object, among others. The paper presents some results of visualization experiments and their corresponding computational fluid dynamics (CFD) simulations, which may be used as a basis for the development of innovative teaching modules.

Introduction

Now, more than ever, engineers are required to focus on sustainable designs that lead to more efficient systems with minimal resource consumption and reduced emissions. Required levels of efficiency can only be achieved with a profound understanding of the involved processes.

Optimization of several engineering systems such as irrigation, sewer collection, water distribution, piping, heating, ventilation and air conditioning systems, aerodynamics and power generation can only be achieved with a deep understanding of fluid mechanics (FM). However, FM is often seen as one of the most difficult core subjects encountered by students in engineering and physics. The problem stems from the necessity to visualize complex flow patterns and fluid behavior usually modeled by high level mathematics. In textbooks and classroom lectures, fluid mechanics is treated as abstract, mathematical and conceptual, even though fluid mechanics is a visual subject. Particle Image Velocimetry (PIV) and Computational Fluid Dynamics (CFD) were adopted in a Fluid Mechanics course at California State University Los Angeles to help students better understand concepts such as streamlines, streaklines and pathlines and their implications in the commonly used Bernoulli's Equation.

Particle Image Velocimetry (PIV) is a unique laser based state-of-the-art technology in fluid flow research that enables visual and quantitative analysis of the flow field; i.e., the fluid velocity as a function of both position and time. No other technology now or in the foreseeable future can do what PIV can. It is widely used in research and industry ranging from aircraft aerodynamics to improving heart implant devices. Some applications in which PIV has been used include (a) system design: where wind tunnel velocity experiments for testing aerodynamics of cars, trains, ships, aircraft and buildings have been done; (b) general research: where velocity measurements in water flows for ship hull design, rotating machinery, pipe flows, channel flows, blood flow, hydrodynamics, spray research, combustion research, wave dynamics, coastal engineering and river hydrology have been implemented; and (c) experimental verification of CFD models.

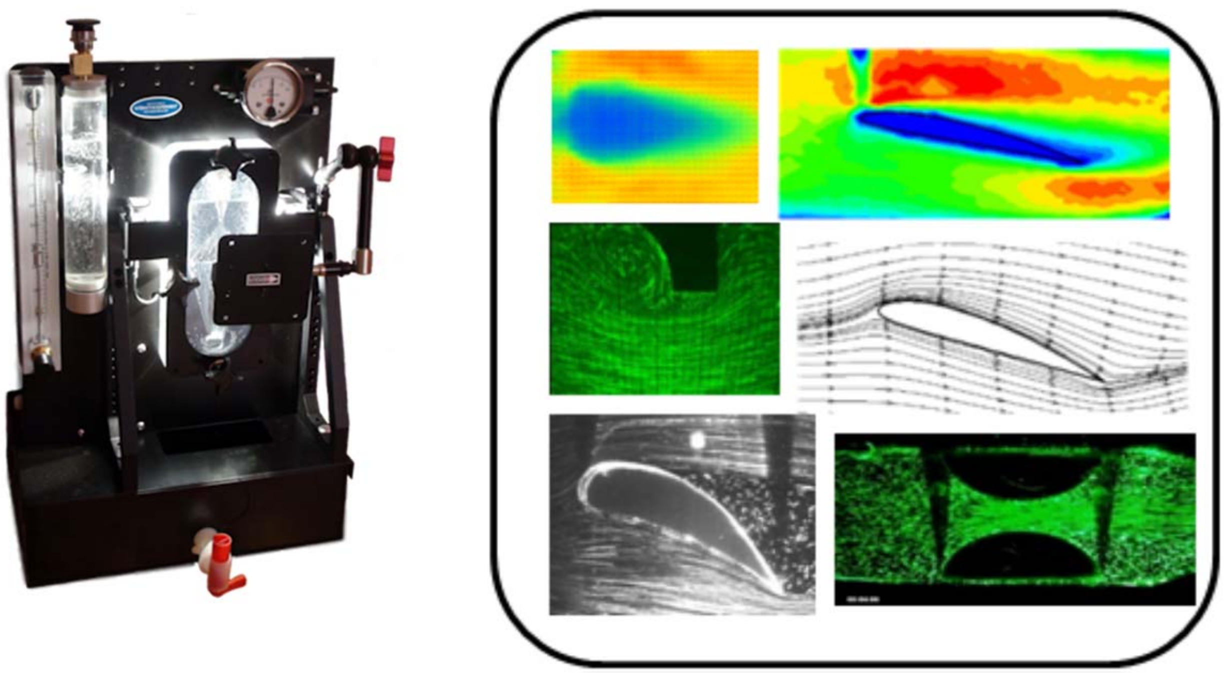
CFD (Tannehill et al., 1997) is a sub-field in fluid mechanics which attempts to solve the detailed governing equations associated with the interaction between the fluid and the body (system), and its corresponding forces via numerical methods. Though the fluid flow can be described mathematically by a set of nonlinear partial differential equations; the resulting system of equations is usually very complex and can seldom be solved analytically. This impediment is handled by means of computers and efficient algorithms that enable quantitative solutions (sometimes in a parametric form) of the fluid flow in a system without the necessity of expensive experimental equipment.

Although PIV is not a novel technology (Hopkinson, 1987; Wernet and Edwards, 1990; and Towers et al., 1991), its elevated cost has made its use for education purposes prohibitive. Recently, Interactive Flow Studies LLC (Interactive Flows Inc.) developed two educational instruments whose aim is to provide support in the quantitative and qualitative analysis of flow around objects, or flow through channels of different sizes and shapes. The instruments developed by Interactive Flows, named FlowCoach (shown in Figure 1) and ePIV, are able to capture images of neutrally-buoyant particles, which reflect light and travel with the flow, allowing for qualitative analysis of the flow field. The data analysis is carried out by means of a linux-based software known as FlowEx. The FlowEx environment uses PIV data to compute parameters of the flow, such as velocity and pressure. FlowEx also provides the option for CFD analysis of flow using Gerris, an open-source framework to solve the governing equations (Popinet, 2003). The FlowEx interface allows for straight-forward CFD analysis of computer-aided-design (CAD) models to estimate velocity and pressure vector fields. These devices enable the comparison of experimental (PIV) and computational (CFD) data.

The potential use of FlowCoach to enhance teaching of fluid mechanics is investigated in this paper. In a laboratory experiment, students used FlowCoach to acquire velocity data for water flowing around a square-shaped obstruction and then computed the pressure change along streamlines using Bernoulli's equation. The experimental data were then compared to the corresponding CFD results obtained for the same conditions.

Teaching Fluid Mechanics

The study of fluid mechanics has benefited from substantial contributions of various well-known scientists such as Archimedes, Leonardo da Vinci, Isaac Newton and Blaise Pascal. An important milestone in the advancement of fluid mechanics was the publication of "Hydrodynamica" in 1738 by Daniel Bernoulli, which led to further investigations by past and current mathematicians, physicists and engineers. As fluid mechanics



(a) (b)

Figure 1. FlowCoach by Interactive Flow Studies: (a) Instrumentation; (b) Sample of results.

continues to evolve, a question still remains. How can the body of knowledge that has been built over centuries be compiled and transferred to junior students over 4-quarter hours. Approaches that vary from regular lectures to more dynamic enthusiastic classes (Blanks, 1979) have been tried. Lately, the use of fluid visualization has been widely proposed and used, especially through the use of CFD approximations (Curtis et al., 2004; Cimbala et al., 2004; Pines, 2004; Sert and Nakiboglu, 2007; and Hu et al., 2008).

The advantage of using CFD is that students are able to visualize velocity fields and construct streamlines, streaklines and pathlines from the detail solution of the governing equations. However, in this case students are only dealing with mathematical models and often it is not easy to relate the theoretical model to the real phenomenon. Therefore, the use of PIV in conjunction with CFD is herein investigated as an approach to enhance teaching of most abstract concepts of fluid mechanics.

Experimental Setup

The FlowCoach equipment helps visualize fluid flow and can aid in the understanding of fluid mechanics concepts such as pathlines, streamlines, and streaklines. The experimental setup consists of a water/fluid reservoir, a flow model manufactured in acrylic, a camera, a set of neutrally-buoyant particles, and a PC containing the FlowEx environment (software) which processes the data. The neutrally-buoyant particles are mixed with the fluid, and travel with it as the fluid is pumped from the reservoir into the flow model section. As the fluid passes through the model section, a camera captures the fluid motion, which is visible due to the reflecting characteristics of the particles. Once the images about the flow patterns have been captured by the camera, they are transferred to FlowEx for processing. FlowCoach uses light-emitting diodes (LED) as a light source whereas the source in the case of the ePIV is a laser. In either case, the flow patterns that are observed provide a true qualitative representation of the fluid flow, as it passes through section where the model is located. The idea behind this type of experiments is that students are able to relate the theory seen in the lectures to the actual visualization of the water flowing around an obstruction. PIV, however, is also able to provide quantitative results.

The motion of the particles is recorded by the camera and divided into a sequence of frames. The current camera records at a maximum speed of 30 frames per second, thus setting the maximum number of sequential frames at 30. It is important to note that the maximum flow rates and velocities that can be resolved depend on the frame rate capability of camera used. After the set of frames has been stored, FlowEx uses the frames to compute the velocity vector field for the flow at hand. The vector field is obtained by comparing a set of consecutive frames and determining the average distance that the particles have traveled. Once the distance has been determined, it is divided by the time interval between each frame, thus producing the velocity output (velocity = distance/time). Since this process is carried out between two consecutive frames, it is called a picture pair. It is important to note that, as more picture pairs are considered, the averaged results provide a better estimate of the actual velocity of the fluid. This technique is called particle image velocimetry (PIV) and produces the average instantaneous velocity of the fluid at a given location. The PIV-velocities provide quantitative data which can be analyzed and compared to the data produced by the CFD. A computer aided design (CAD) representation of the system is integrated into the numerical scheme that solves the mathematical equations describing the fluid motion. CFD outputs velocity and pressure vector fields at each node of domain under consideration.

The advantage of using FlowCoach is that it enables qualitative (visual) analysis without the need of any computer or data processing; it also allows for flow control. The disadvantages of using FlowCoach, since it is an experimental system, are that at (1) high flow-rates (i.e., high velocities) the PIV analysis produces inaccurate results, (2) we are limited to using 30 frames/second (though the camera can be replaced for one with higher resolution), and (3) the analysis depends on the positioning of the camera which makes direct comparison between PIV and CFD more complicated. It should also be noted that the analysis is limited to steady flows.

Preliminary Tests

The experiments were conducted by a class 20 students. The students were divided into five groups of four. Each group was instructed on how to setup the experiment, perform the analysis and collect their own set of data. On average, each group spent approximately 1 hour to complete the lab. The PIV analysis run time is dependent on the level of discretization, and can range from 5 minutes to more than 1 hour. Parameters that had proven to offer good results while maintaining a relatively short computing time (15 minutes) were provided to the students. While students waited for the PIV results, Flowex was used in different computer to run the CFD analysis. Students were then asked to compare the numerical results against the experimental data.

The experimental test consists of flow visualization around an obstruction with shape of a square, and determination of the velocity field using particle image velocimetry (PIV) analysis of the flow around such an object. The numerical test, on the other hand, consists of performing a computational fluid dynamics (CFD) study of the flow under same conditions of experimental setup. Although direct comparison of velocity fields provided by both PIV and CFD is possible, one of the objectives of the class was to reinforce the learning of fluid dynamics concepts such as streamlines, pathlines and streaklines. Thus, the validation is carried out by calculating the change in pressure along a streamline using Bernoulli's equation.

Bernoulli's equation can be derived from the application of Newton's law to an inviscid fluid particle moving in a steady flow along a streamline. If the flow is also incompressible, this equation can be written as

$$\frac{p}{\gamma} + \frac{v^2}{2g} + z = \text{Constant}$$

(1)

where p is the thermodynamic pressure (also commonly known as static pressure), vv is the fluid velocity and z its position (elevation) with respect to a fixed coordinate system; γ is the fluid specific weight and g the well-known gravitational constant. During the lab session, students are encouraged to discuss on how the assumptions used in the theoretical development of Bernoulli's equation may affect the results obtained by experimental data, in which such assumptions are often not valid.

Equation (1) relates pressure changes to changes in velocity and elevation. In general, the value of the constant in the Bernoulli equation is different on different streamlines. The streamlines in the experiment can be observed qualitatively by tracking the particles flowing with the fluid (water). Figure 2 shows a 3-image sequence captured 1/30 s apart. In this sequence it is possible to notice the movement of particles, as highlighted in Figure 1. PIV uses the position at different times to develop the velocity field vectors (Figure 3), allowing for quantitative analysis of the flow.

Velocity fields obtained from CFD and PIV are compared, quantitatively, by computing the pressure differential between points along particular streamlines. Reference points in a streamline are identified through visual inspection of the CFD-based velocity field and verified using Bernoulli's constant shown in Equation (1), using output values of velocity and pressure from the numerical solver. The reference points are then located on the PIV velocity vector field as seen in Figure 4. Assuming that the points have the same location with respect to the square-shaped obstruction, the pressure difference between these two points should be the same in both PIV and CFD results. The pressure differential between these two points (positions x_1 and x_2) is calculated with a modified version of Equation (1), for relative small changes in z position [see Equation (2)], for 5 different streamlines, as depicted in Figure 5.

$$\Delta p = \frac{\rho(v_2^2 - v_1^2)}{2}$$
(2)

where ρ is the fluid density. The corresponding results are shown in Figure 6. The results show a reasonable agreement between PIV and CFD, with the standard deviation varying 0.89 to 0.99.

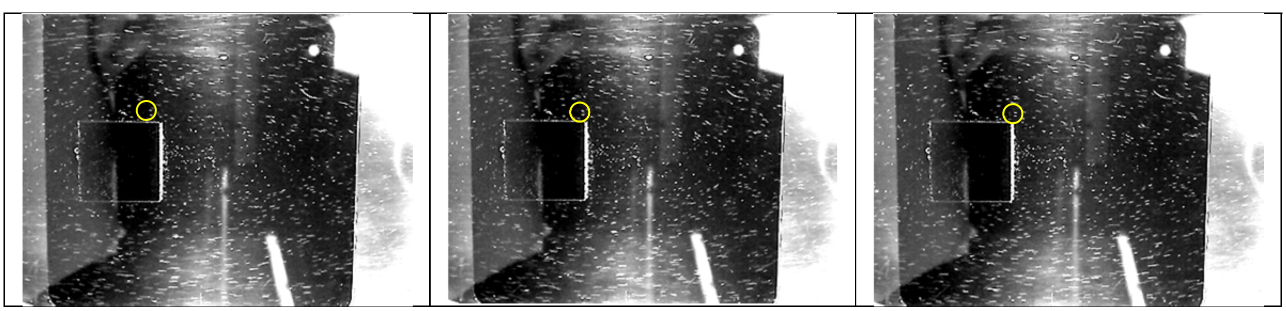


Figure 2. Sequence of images obtained by FlowCoach for PIV analysis (note: the yellow circle in the images depict the region where tracking of two particles, as they move around the obstruction, is done).

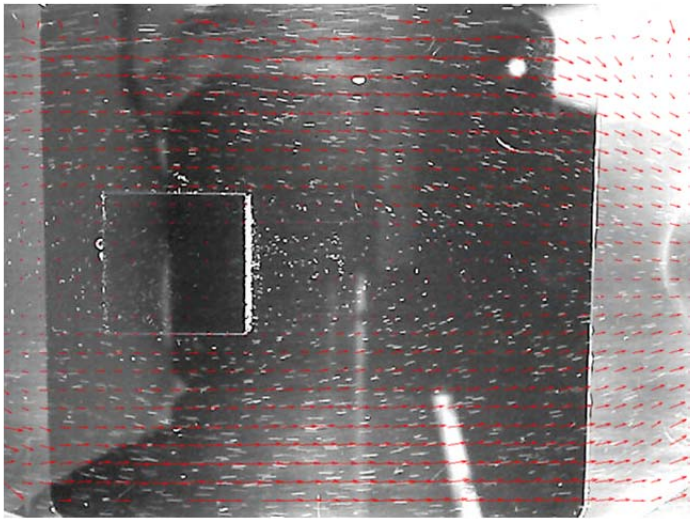


Figure 3. Velocity field obtained using FlowCoach particle image velocimetry (PIV).

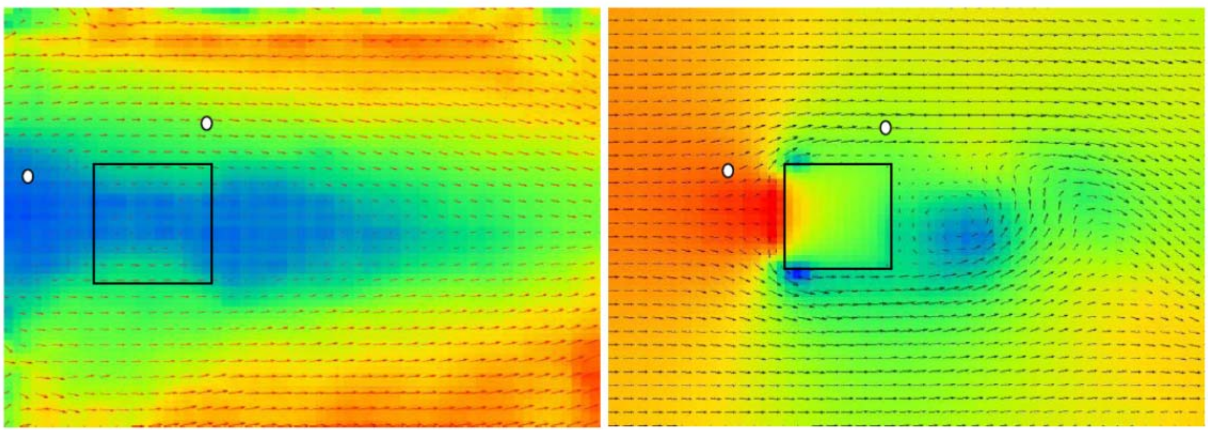


Figure 4. Velocity vector field from (a) Experimental data by PIV, and (b) Computational data by CFD.

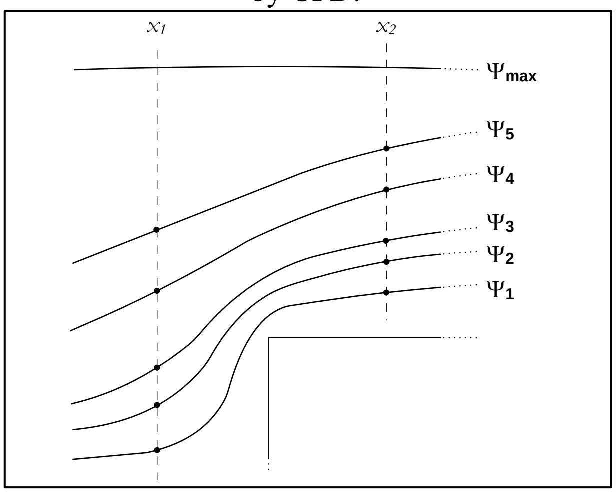


Figure 5. Sketch of streamlines of a flow through a square-shaped obstruction and location of reference points used in pressure change calculation

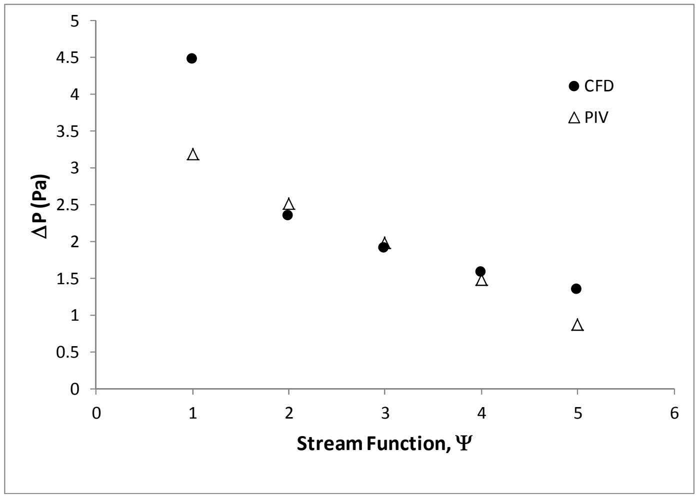


Figure 6. Comparison of local values of ΔP between two *x*-locations along streamlines.

Future Directions

The results of this preliminary study indicate that CFD along with PIV visualization capabilities may have a positive impact on students learning of abstract concepts in fluid mechanics. Thus, the next steps that will be undertaken are directed to the development of additional teaching modules and the corresponding effective assessment/evaluation tools.

Acknowledgements

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Application of Ultra Wide Band Radar for Multiple Human Tracking with CLEAN Algorithm

(Education of Radar System through Graduate Project)

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1. Introduction

Radar systems consist of RF hardware and a signal processing unit. The RF hardware generates high frequency signals, transmits and receives it to detect echoes from a target. The signal processing unit processes data received from the hardware to recognize the target and extract information about it. Therefore, a project using a radar system can provide an opportunity for students to acquire knowledge and hand-on experiences on hardware as well as software.

Multiple human tracking is an interesting topic due to the increased demand for security and surveillance. To track human subjects, diverse technologies have been developed, including computer vision, infrared detectors, Ladar and radars. Among them, radar offers a unique advantage compared to the other technologies because it has the ability to penetrate through obstacles and detect targets in all weather conditions [1]. The use of ultra-wide band (UWB) radar is an immerging technique that has high resolution for target detection. The use of UWB radar for human detection has been researched. A human subject was distinguished from animals and vehicles through use of the CLEAN algorithm [2, 3]. Through the investigation of the change of the returned pulse shape, human activities were also classified [4]. Multiple target tracking with target signatures, however, has not been extensively researched. Therefore, it can be a proper graduate project for the purpose of education as well as research.

In this project, we proposed a method to track multiple human subjects using UWB radar based on the time varying target signature. We solve the correspondence problem that occurs when target echoes overlap. The human walking signature is used to discriminate the subjects. Each human has its own walking style such that the target can be recognized by the talking (walking?) style. We employ the CLEAN algorithm to characterize human posture at an instant. Because human motion should be examined by a series of postures, we consider the time-varying signature of the coefficients. Two walking humans are measured using UWB radar; they are classified and tracked by the suggested method. Measurement, signal processing and analysis are performed by graduate students.

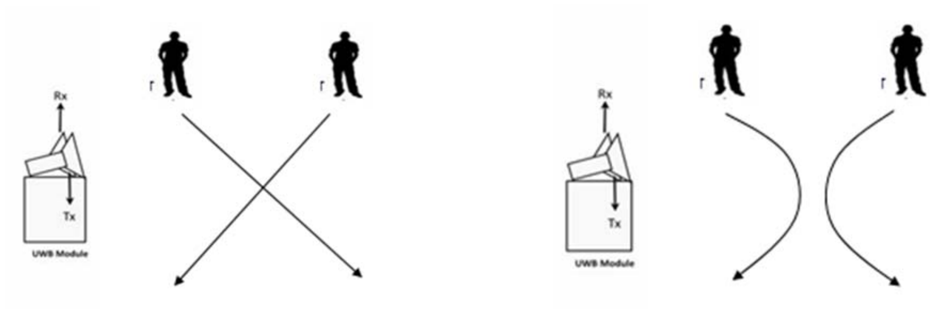
Four main learning objectives are pursued in this project. They are: (i) students understand the basic concept of UWB radar system, (ii) students operate the UWB radar to measure human movements, (iii) students understand diverse signal processing algorithms, (iv)students implement each signal processing block using MATLAB.

2. Measurement and Pre-Processing

Two walking human subjects are measured by P220 UWB radar manufactured by Time Domain Co. Ltd. The graduate students are trained to operate the UWB radar system, which consists of two P220s, two horn antennas, a router and a computer to record the data for the bi-static operation. We use high-gain horn antennas for the purpose of increasing signal power illuminating the target. Figure 1 represents one example of the measurement setup.

Figure 1: Human subjects with UWB radar

Two human subjects walk in from of the radar with their own walking style. The whole setup is placed in an open space so that there is no other reflecting object in the neighborhood that causes interference except the reflection of the signal from the ground. In order to make the walking style distinct, one human subject walks with a large arm swing or carries a cylindrical reflector. We tested two scenarios as shown in Figure 2.



(a) (b)

Figure 2: Two measurement scenarios

In the first case, the echoes from each person cross each other in the range profile because one human subject moves forward and the other moves backward with respect to the radar. On the other hand, the echoes do not cross each other in the second scenario. The data recorded during the measurements need to be pre-processed for tracking. The graduate student performed pre-processing including elimination of the direct and normalization of data using MATLAB. Figure 3 shows a sample range profile in a single scan.

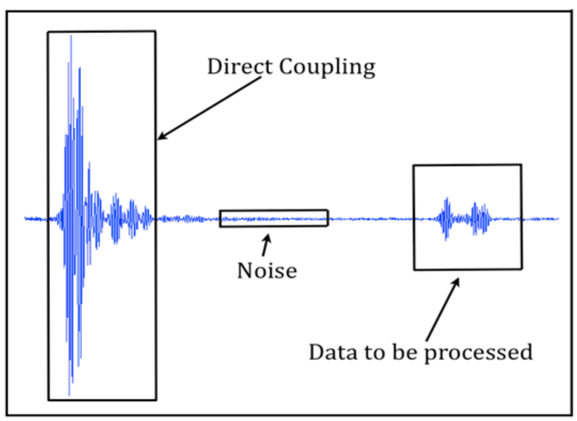


Figure 3: Range profile of single scan

The figure shows that there is direct coupling between the Tx and the Rx antennas and two echoes from the two human subjects. To remove the direct coupling and reflected signals from ground clutters, we subtract the ambient signal from the measured signal. The ambient signal is measured without human subjects to capture ground clutters and noises. Then echoes are extracted and normalized to remove the distance effect and reduce the complexity of the data. Because the pulse shape depends on, not the distance but, the posture of the human, we take the echoes only and normalize the amplitude. The normalized signal is analyzed by the CLEAN algorithm.

3. Recognition by CLEAN Algorithm

When a human subject is illuminated by an UWB signal, the received signal can provide distinguishable information about the target. A complex subject shape returns multi-path components from different body parts at different times with various amplitudes. Therefore, the returned echo at an instant is composed of superposition of multiple returned scatters from the different parts of the human body. We employ the CLEAN algorithm to decompose the received echo into several template signals. The CLEAN algorithm is developed to detect a weak target in the presence of a strong target through subtracting the response of a strong target from the total response, in astronomy. It has been applied to the analysis of human scatters as well. Humans could be successfully classified among animals and vehicles [2, 3]. In our study, the CLEAN algorithm can estimate time-delay and amplitude of each scatter of the human body with the provided template waveform. The graduate student implemented the CLEAN algorithm using MATLAB to decompose the human echoes with the five template signals. An echo from a cylindrical reflector is used as a template signal. Through cross-correlation, the coefficients of the CLEAN algorithm are computed, resulting in five time-delays and five amplitudes. The iterations can be extended further to decompose more scatters, but we set the number of iterations to five because it is found to be sufficient empirically.

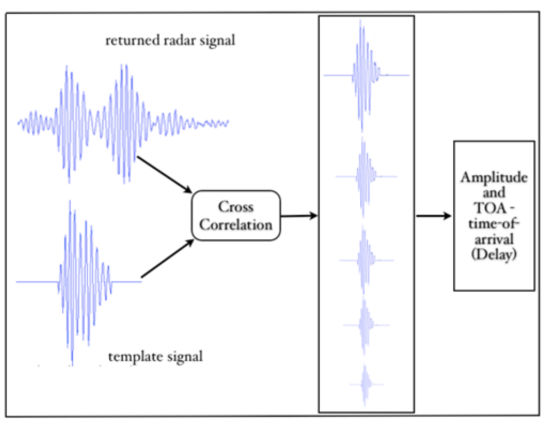
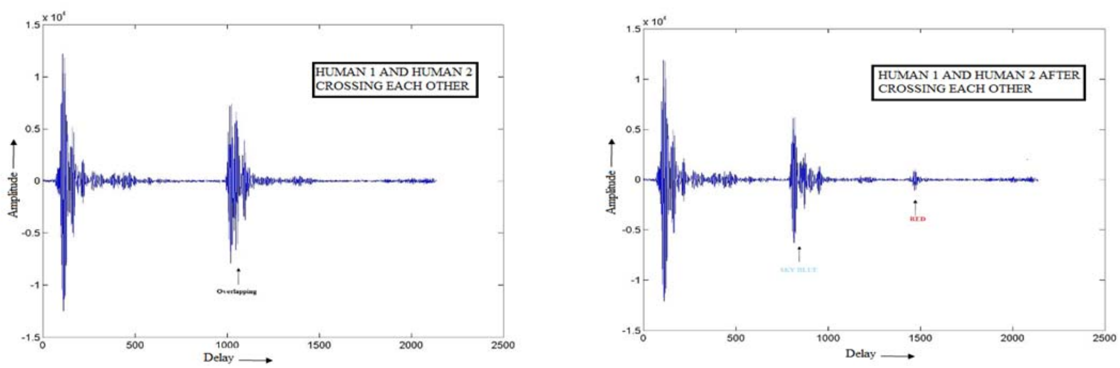


Figure 4: Concept of CLEAN algorithm

As a result, the estimated ten coefficients of the CLEAN algorithm correspond to a certain human posture. However, the walking style is not determined by the coefficient itself, but how the coefficients vary with time. Under the assumption that each human has its own unique walking style, the time-varying characteristic of the CLEAN coefficients is utilized to capture the signature of a walking style. We consider the mean and variance of CLEAN coefficients as a signature. Those are basic but contain significant information. Within the time window, the normalized echoes are analyzed by the CLEAN algorithm. We set the time window to 1.5sec. The mean and variance of the ten coefficients within the window are investigated for classification. Through calculating the similarity of features between before and after the echoes overlap, two human subjects could be successfully distinguished. The result is shown in Figure 5.



(a) (b)

Figure 5: Tracking result

4. Conclusion

We investigated the feasibility of solving the correspondence problem in multiple human tracking using the CLEAN algorithm based on human walking features. The signal obtained after reflection from the human subject is first pre-processed to remove the direct coupling and the background noise. The CLEAN algorithm uses the pre-processed human scatters to extract the feature of the return. The features are used for the classification in multiple human tracking. The suggested algorithm successfully classified the two humans. This project could provide an environment for the students to operate the UWB radar and to learn signal processing techniques including cross-correlation, normalization and the CLEAN algorithm. Three main learning outcomes are obtained through this project. First, students learned basic concept of UWB radar such as pulse repetition ratio and signal integration by operating the radar. Second, students understood the concept of the CLEAN algorithm to decompose UWB echoes. Third, students could implement a number of algorithms using MATLAB.

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Communications Laboratory with Commercial Test and Training Instrument

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Abstract

A communications laboratory course has been designed around the Telecommunications Instructional Modeling System (TIMS) of Emona Instruments. This instrument includes a sampling oscilloscope and spectrum analyzer, the PicoScope of Pico Technology.

There are three main learning objectives for this laboratory course. First, students use fundamental concepts of signals and systems in different situations, gaining more fluency with these concepts. Second, students rehearse the important techniques of communications, including modulation, demodulation, synchronization, and sampling. Third, students get more practice and acquire more confidence in experimental methods.

Introduction

A laboratory course was developed to complement a lecture course ("Communication Engineering") that covers Fourier series and transforms, filtering, analog modulation and demodulation, synchronization, sampling, and receiver architectures. The laboratory course uses the Telecommunications Instructional Modeling System (TIMS) of Emona Instruments [1], see Figure 1. This instrument incorporates a sampling oscilloscope and spectrum analyzer called the PicoScope [2]. The PicoScope is connected (by means of a USB) to a desktop computer, whose monitor and mouse provide the display and control. This paper summarizes the learning objectives of this laboratory course and then discusses some typical experiments.

The TIMS instrument comes with a set of removable modules that permit a wide variety of communication circuits to be built and tested. There are signal generators of different type, including oscillators, pulse train generators, and pseudorandom noise (PN) code generators. A selection of filters is offered. There are narrowband phase shifters and quadrature phase splitters. Some modules enable arithmetic operations, such as multiplication and weighted summation. There are a number of modules that support frequency control, such as a voltage-controlled oscillator (VCO), frequency multipliers, and frequency dividers. A great selection of advanced modules are available for the TIMS instrument, but even with just the basic set of modules, it is possible to demonstrate the most important ideas covered in an introductory course in communication systems.

The advantage of a modular communication test and training instrument like TIMS is that it permits rapid exploration of design concepts using physical circuits. In one laboratory session, students can implement a transmitter and receiver, make measurements, and experiment with the optimization of system parameters. An instrument with similar functionality, the Berkeley Communication Laboratory, was used at the University of California Berkeley in the 1970s [3].

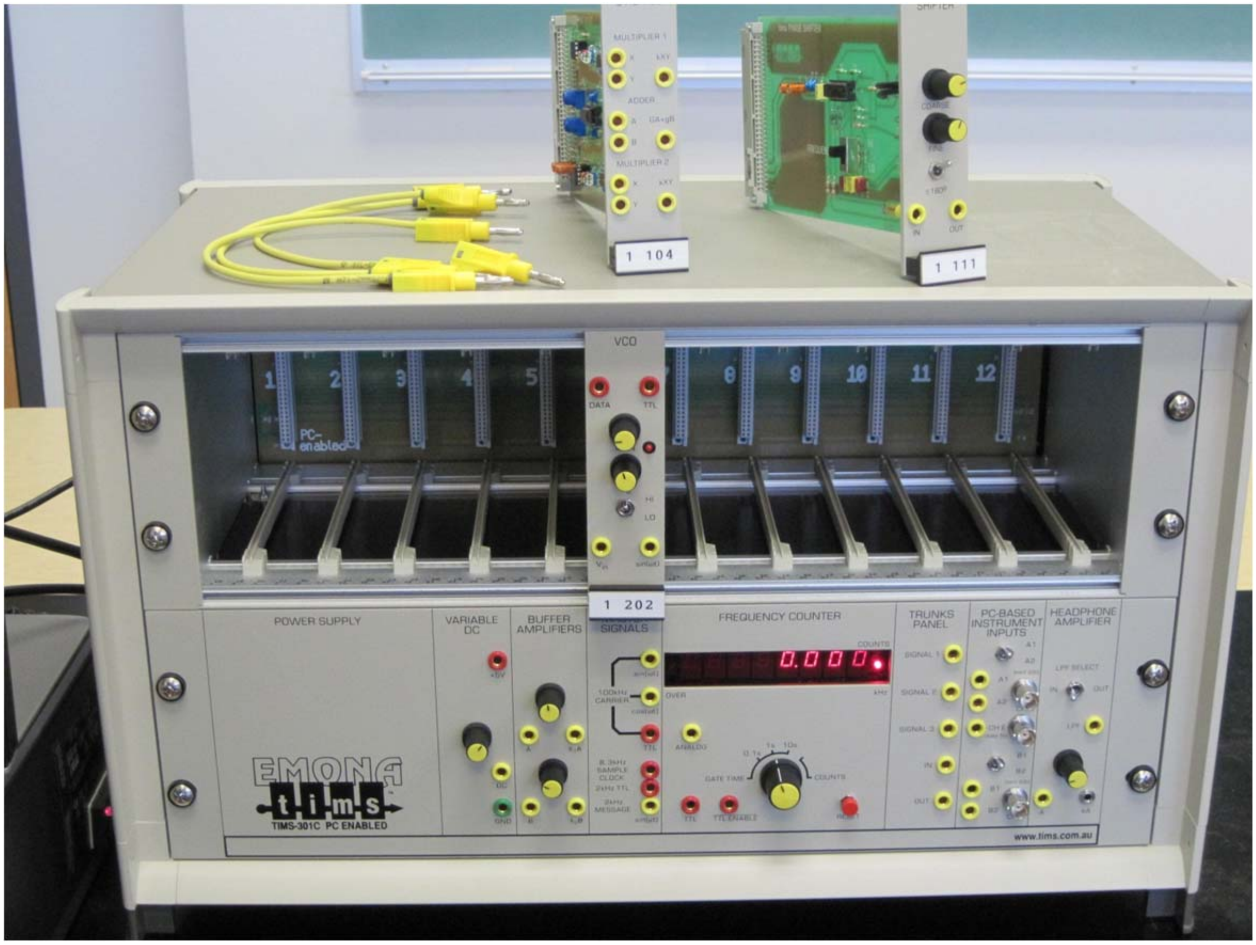

Figure 1: Telecommunications Instructional Modeling System (TIMS), Emona Instruments

Learning Objectives

There are three main learning objectives for this laboratory course. First, students use fundamental concepts of signals and systems in different situations, gaining more fluency with these concepts. Second, students rehearse the important techniques of communications, including modulation, demodulation, synchronization, and sampling. Third, students get more practice and acquire more confidence in experimental methods.

Throughout the series of laboratory exercises, students see the principles of signals and systems in action. They see how the time domain, as viewed on an oscilloscope, and the frequency domain, as viewed on a spectrum analyzer, permit complementary descriptions of a signal. Students exercise what they've learned about aliasing when they use the sampling spectrum analyzer. They see how different classes of systems react to sinusoids and weighted sums of sinusoids. For example, the following properties of systems are observed. A linear, time-invariant system produces no new frequencies at its output that are not present on the input. A nonlinear system produces harmonics. A time-varying system produces, in general, frequencies that are not present on the input and are not harmonics.
Students rehearse what they learn in a communication systems lecture course. In the

communications laboratory they implement and test several modulation schemes and demodulation methods. These include: double-sideband and single-sideband modulation with synchronous demodulation, amplitude modulation with envelope detection, frequency modulation with both zero-crossing and phase-lock demodulation. Students build and test closed-loop synchronization circuits: a simple phase-locked loop and a Costas loop. Students experiment with receiver architectures: superheterodyne and Weaver.

Students learn about good experimental technique. They learn that a periodic signal can be used to achieve a stable oscilloscope display while affording continuous capture of that signal. They learn the importance of gain in a succession of stages and about the need to prevent overload. They get accustomed to thinking in terms of decibels. They experiment with different phase relationships among sinusoids and how these relationships can be exploited in certain receiver architectures.

The students were queried about the perceived value of this course to their careers. The results of that survey are shown in Table 1. Since this course is new and not a modification of an existing course, there are no previous results with which to compare the data of Table 1.

Table 1: Survey of Students

"This course enhanced my …"	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
"… skills to formulate and solve problems."	73%	27%	0%	0%	0%
"… ability to do engineering."	73%	27%	0%	0%	0%

Experiments

The complete list of experiments for this laboratory course is given in Table 2.

Experiment 1. Students become acquainted with TIMS and with the use of the oscilloscope and spectrum modes of the PicoScope. They see the response of different classes of systems to a sinusoid. An amplifier (with small-signal input) serves as an example of a linear, time-invariant system. A clipper exemplifies nonlinear systems, producing harmonics. A multiplier together with local oscillator (that is, a frequency converter) is representative of linear but time-varying systems.

Experiment 2. With TIMS the carrier is 100 kHz. The message signal can be a sinusoid or recorded audio. In this experiment double-sideband modulation is used with synchronous demodulation. A carrier "stolen" from the transmit side is used in the synchronous demodulator. (This is corrected in a later experiment, after phase-locked loops have been introduced.)

Experiment 3. Amplitude modulation is employed with envelope detection. The message is first a sinusoid and later recorded audio. In the latter case, the X-Y mode of the oscilloscope is found to be useful for adjusting the modulation index.

Table 2: Experiments

1	Linear time-invariant systems, nonlinear systems, time-varying systems
2	Double-sideband modulation, synchronous demodulation
3	Amplitude modulation, envelope detection
4	Single-sideband modulation
5	Single-sideband demodulation
6	Frequency modulation, zero-crossing detection
7	Armstrong (narrowband) phase modulator, frequency multiplication, FM spectrum
8	Superheterodyne receiver, Weaver architecture
9	Phase-locked loop, Costas loop
10	Phase-locked loop demodulation of FM
11	Pulse width modulation
12	Ideal sampling, sample-and-hold
13	Binary phase-shift keying, Costas loop demodulation

Experiment 4. A single-sideband modulated carrier is produced. In the first instance, a sinusoidal message is employed and the necessary 90° phase shift of that message is accomplished with a narrowband phase shifter. In the second instance, a quadrature phase splitter provides a wideband 90° phase shift.

Experiment 5. A single-sideband carrier with an audio message is recovered with a synchronous demodulator, and this is found to work well as long as the (receive-side) local oscillator has a frequency within a few hertz of the carrier. Then a true signal-sideband demodulator is built using a phasing technique; this demodulator is found to be sensitive only to sidebands on one side of the carrier.

Experiment 6. Frequency modulation is implemented with a voltage-controlled oscillator (VCO), and demodulation is done with a zero-crossing detector. The frequency deviation is set using the method of Bessel nulls when the message is sinusoidal.

Experiment 7. A narrowband phase (Armstrong) modulator is implemented, and the frequency deviation is increased by frequency multiplication. The spectrum of an angle-modulated carrier with a sinusoidal message is studied.

Experiment 8. Two different receiver front-ends are implemented and studied. The first is the classic superheterodyne receiver, for which the problem of the image frequency is solved with a bandpass filter in front. The second receiver architecture is that due to Weaver, for which the image frequency is canceled through careful phasing.

Experiment 9. A phase-locked loop is built. Phase-lock to a 100-kHz unmodulated carrier is achieved. A Costas loop is built, and it is used for carrier synchronization on a double-sideband modulated carrier, obviating the need for a "stolen" carrier. Demodulation is achieved in the same circuit.

Experiment 10. A frequency modulator is implemented as an integrator, followed by an Armstrong (narrowband) phase modulator, followed by frequency deviation multiplication. Demodulation is accomplished with a phase-locked loop.

Experiment 11. A pulse-width modulator is calibrated. Using a sinusoidal message, a PWM signal is double-sideband modulated onto a 100-kHz carrier. Envelope detection and filtering is used to recover the original message.

Experiment 12. Multiplication of a low-pass message signal by a pulse train is used to approximate ideal sampling. The relationship between message bandwidth and sampling frequency is investigated. Recovery of the original message is accomplished through filtering. The more practical sample-and-hold circuit is then demonstrated.

Experiment 13. Binary phase-shift keying (BPSK) is implemented as an example of digital communications. A Costas loop receiver is used for carrier synchronization and demodulation.

Example: BPSK with Costas Loop Demodulation

This section illustrates the capability of TIMS by offering more detail on Experiment 12.

As usual for TIMS, the carrier frequency is 100 kHz. The data come from a PN code generator. BPSK is accomplished with a multiplier. The receive side consists of a Costas loop, which provides carrier synchronization and demodulation. A block diagram of a Costas loop appears in Figure 2.

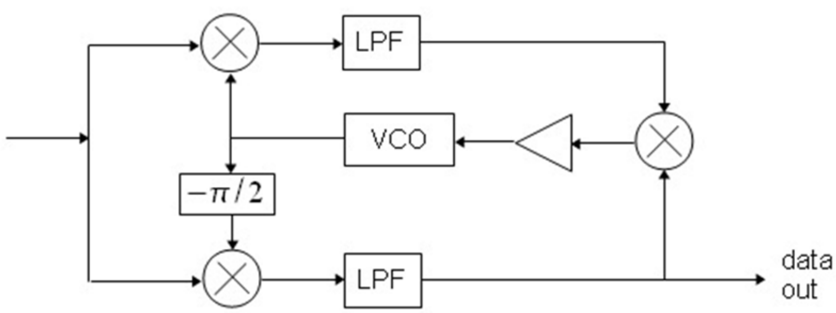

Figure 2: Costas Loop

The Costas loop is an interesting example of feedback control. As implemented here, this is a first-order loop, and its tracking properties are therefore poor. This means that getting the loop to lock requires that the best-lock frequency of the VCO must be close to the carrier frequency. Moreover, the total loop gain must lie within a fairly narrow range. Figure 3 shows the experimental arrangement.

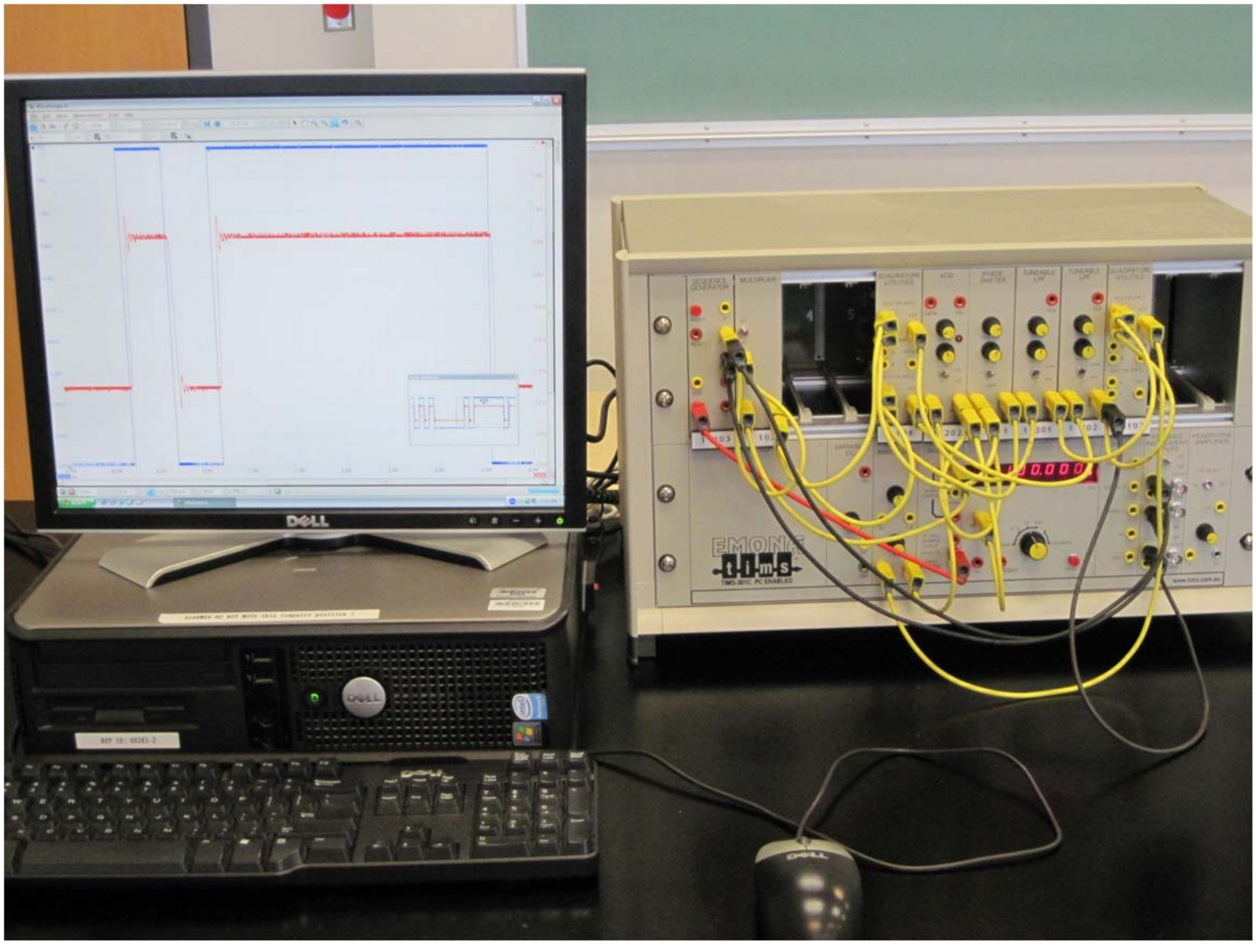

Figure 3: BPSK Modulator and Costas Loop Demodulator as Implemented on TIMS

The total loop gain is positive in this arrangement, and as a result the recovered data appear at the output of the low-pass filter (LPF) on the bottom branch of the loop that is illustrated in Figure 2. Because of the two-fold phase ambiguity inherent in a Costas loop, the data may have either correct or opposite polarity. Students experiment with taking the loop in and out of lock, in order to see that the data sometimes appear “right-side up” and sometimes “upside down”, depending on which of two stable lock points is realized.

Students also change the algebraic sign of the total loop gain, making it negative; and this causes the data to appear (either of correct or opposite polarity) on the top branch of the loop that is illustrated in Figure 2. Students gain a good intuitive understanding of the phase relationships in the Costas loop by experimenting with the two-fold phase ambiguity and with the algebraic sign of the total loop gain.

Figure 4 shows the PicoScope display for the original (transmit-side) data (in blue) and the recovered data (in red) appearing on the bottom branch of the Costas loop (with positive total loop gain).

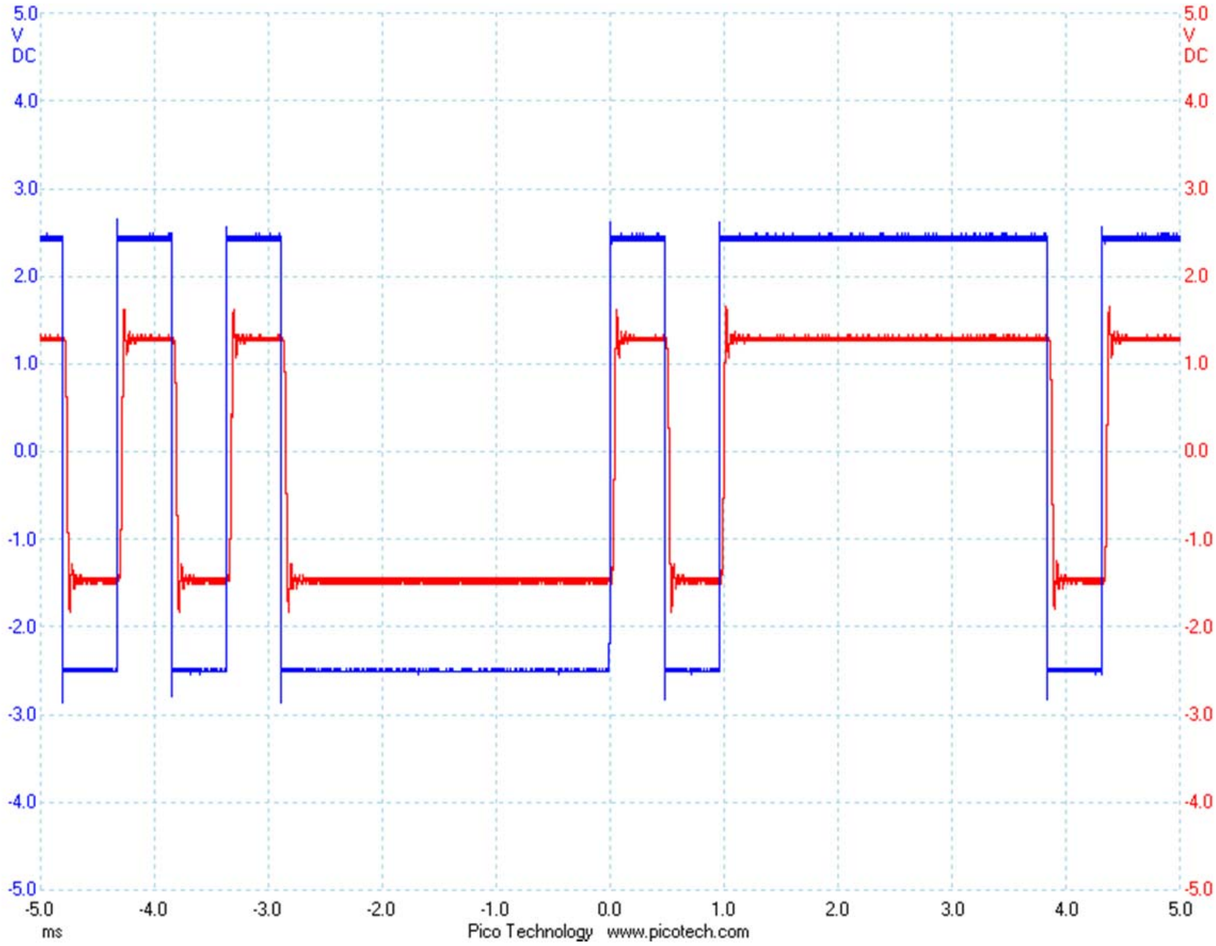

Figure 4: Data at Transmitter (Blue) and Recovered Data in Costas Loop Receiver (Red)

Conclusions

A communications laboratory course was developed around the TIMS instrument. Modular in design, this instrument permits rapid exploration of design concepts. The course has three main learning objectives. First, students gain more fluency with fundamental concepts of signals and systems. Second, students rehearse the important techniques of communications. Third, students acquire more skill and confidence in experimental methods.

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A Truss By Any Other Name May Still Not Be a Truss: A 'Do-Say' Pedagogical Laboratory Exercise

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Abstract

Contrary to common perception, undergraduate education in engineering mechanics does not need reform. Basic aspects of mechanics (e.g., strength of materials, mechanical behavior of materials, experimental mechanics, etc.) are still necessary components of any Mechanical Engineering program. Instead, what does need reform is the delivery system and the tools used by students and faculty in learning and teaching engineering mechanics. In this paper, an example of such a change in the delivery system and learning tools is highlighted. The course which contains this example is an experiential learning "do and say" Mechanics of Materials Laboratory. The highlighted example is a strain gauged bicycle frame. The premise of the laboratory exercise is that although the bicycle frame appears to be a truss, it is not because many of the assumptions inherent in truss analysis are violated. Students must prove that the bicycle frame is not a truss by triangulating on the proof of their hypothesis using analytical, experimental and numerical methods. Student surveys and course evaluations indicate that this laboratory exercise is one of their favorites in the course. In addition, they indicate that the exercise is particularly good at helping them "put the pieces together" so as to really understand the subject.

Introduction

Experiential learning is not only "in-vogue" in engineering education, it is an acknowledgment of how human beings assimilate information. Because human beings are tactile animals, we learn best by coupling our sense of touch with our senses of sight, hearing, smell and even taste to provide maximum efficiency to information uptake and utilization.

Communication (oral or literary), when coupled with experiential learning exercises reinforces the information assimilated during the exercises. Indeed the "cone of learning" shown in Figure 1 clearly indicates that greater than 90% retention can be achieved if a learning experience involves a "do-say" aspect. A laboratory experiment with a formal written laboratory report is an example of such a "do-say" exercise. This 90% level of retention is in contrast to only 10% retention achieved through reading only such as in reading assignments out of a textbook or an information search on the World Wide Web. The efficacy of active versus passive learning for increasing retention of new information is shown graphically in Figure 1.

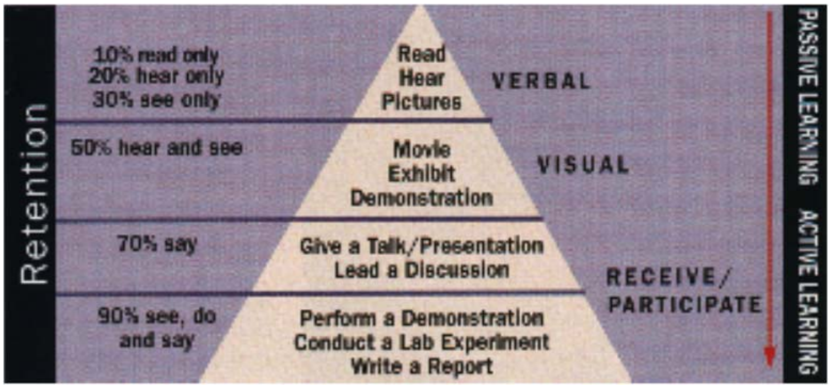

Figure 1 – Cone of learning showing increased retention of information with active learning (from Ref [1])

Engineering mechanics, and in particular, mechanics of materials (MoM), is an essential aspect of any mechanical engineering program. Although it is possible for engineering students to apply the appropriate equations and perform well on homework exercises and exam problems within any academic period, there may be concern about how long students retain their newfound MoM knowledge following the academic period in which they first learned it. This concern is especially important for instructors of courses that require MoM courses as prerequisites.

How much and how well students learn can be assessed if engineering instructors (who seldom have formal training in pedagogy) are cognizant of such concepts as Bloom's taxonomy of cognitive domain[2] and Sousa's illustration of the complexity and difficulty within the taxonomy[3]. The lowest to the highest levels of complexity of the taxonomy include knowledge, comprehension, application, analysis, synthesis, and evaluation. While complexity is associated with the level within the taxonomy, difficulty establishes the amount of effort required within each level[4].

Interpreting the taxonomy from the passive versus active learning illustration shown in Figure 1 implies that acquiring knowledge (lowest level of complexity) can be achieved primarily passively (point of the cone of the learning) but with the lowest level of retention. Evaluating and synthesizing information and concepts (greatest level of complexity) can only be achieved actively (base of the cone of learning) thereby promoting the greatest level of retention.

Thus, experiential learning coupled with communication (e.g., a laboratory exercise followed by a formal engineering laboratory report incorporating description, analysis, and discussion), has long been employed to promote understanding and retention in engineering education. In the past, experiential learning has been employed not because it was dictated by formal training in pedagogy, but also because its efficacy is apparent by observation of the success of students in learning the subject matter.

The advent of new accreditation criteria (EC2000)[5] introduced by the Accreditation Board for Engineering and Technology (ABET) has formalized how engineering instructors view not just teaching, but also how students learn. Program objectives, educational processes, assessment

/evaluation, and feedback are essential aspects of how engineering programs achieve their academic aims. Teaching students to learn as well as assessing how well students learn are integral parts of this new paradigm in engineering education.

In this paper, the background of a mature "do-say" course in engineering mechanics, "Mechanics of Materials Laboratory" is first described. Then, one of the exercises (Structures) within the course is presented in detail followed by a brief discussion of assessment and evaluation of the success of student learning. Finally, some conclusions are drawn regarding the teaching and learning aspects of this exercise.

Background

Curriculum revisions at various institutions have been effected to respond to changing needs of BSME graduates entering engineering practice. Within the mechanics and materials sub discipline, lecture-only mechanics of materials courses can be modified to include an expansive experiential-based mechanics of solids/behaviour of materials course. The rationale behind this move is that a single experiential-based course would promote more retention and enhance student learning by focusing on the active learning mode of "do-say" exercises[1, 6].

As shown in Figures 2 and 3, an additional benefit of this curricular change was that students were given more flexibility in option courses. Credits in the remaining mechanics and materials courses can be adjusted to reflect re-emphasis of experiential learning within those courses.

Of particular importance in this curriculum revision was the synergism of "Mechanics of Materials" (MOM) and "Mechanics and Materials Laboratory" (MOML)[6]. MOM is often based on computer-driven lecture and tutorial course material, team-oriented quiz/homework sections, and in-class demonstrations. This course lays the groundwork of mechanics of materials.

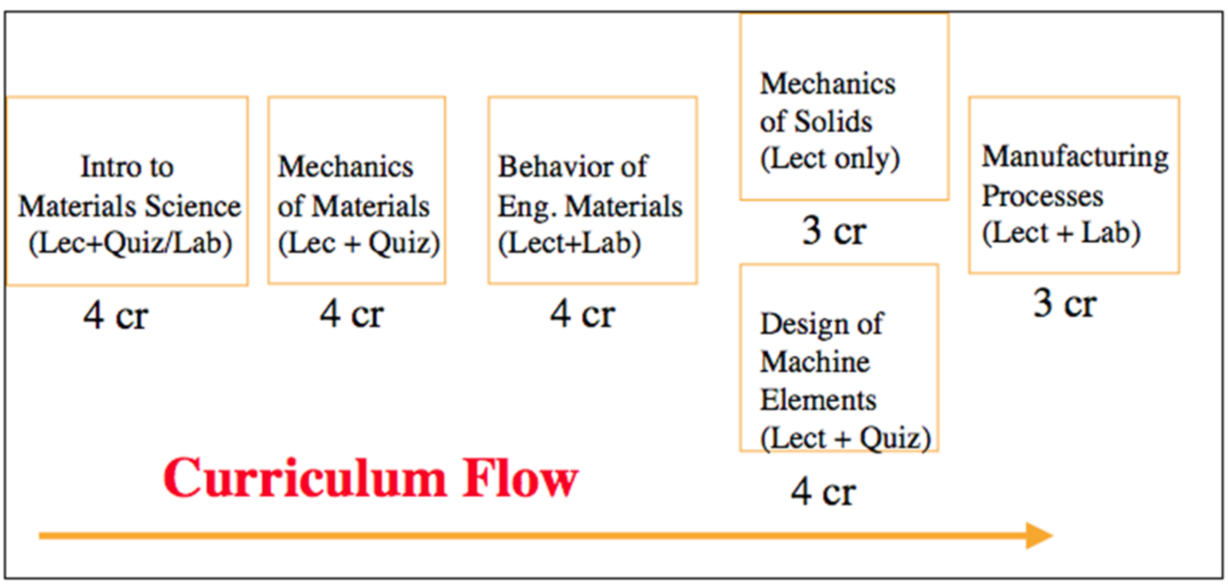

Figure 2 Conventional curriculum flow within the mechanics and materials subdiscipline

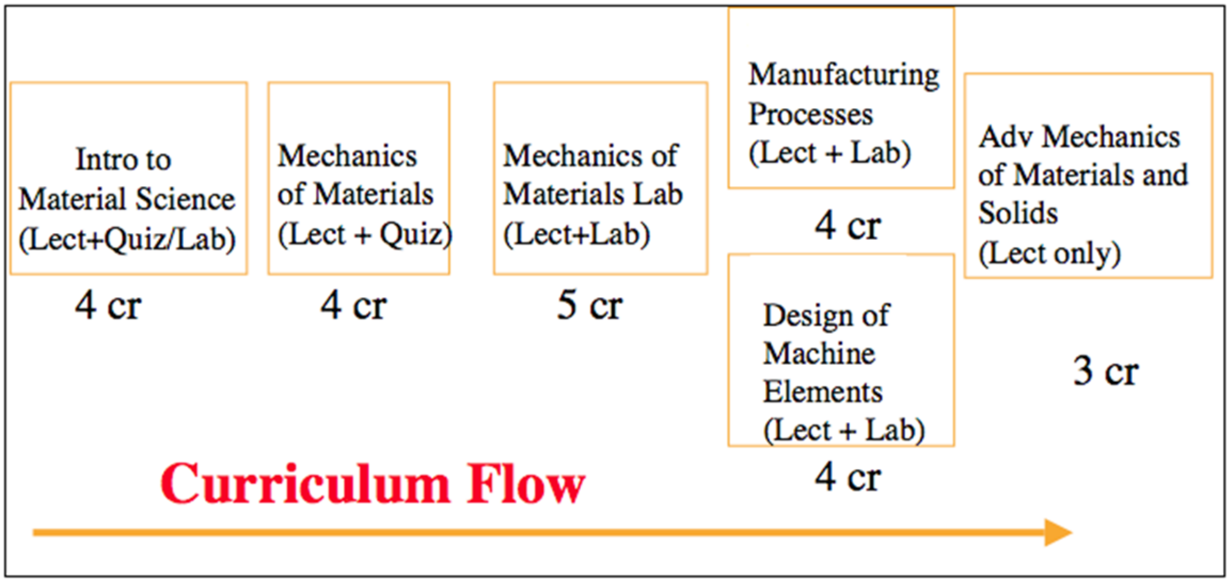

Figure 3 Revised curriculum flow within the mechanics and materials sub discipline (note that the 5-credit MOML course is the new experiential learning course)

MOML has an experiential-learning, hands-on laboratory format (see Figure 4) that reinforces concepts of MOM as well as extending basic Mechanics of Materials into more advanced concepts. Web-based course/lab notes, spreadsheet-based solution paths, comparison and contrast of experimental, analytical and numerical solutions are key features.

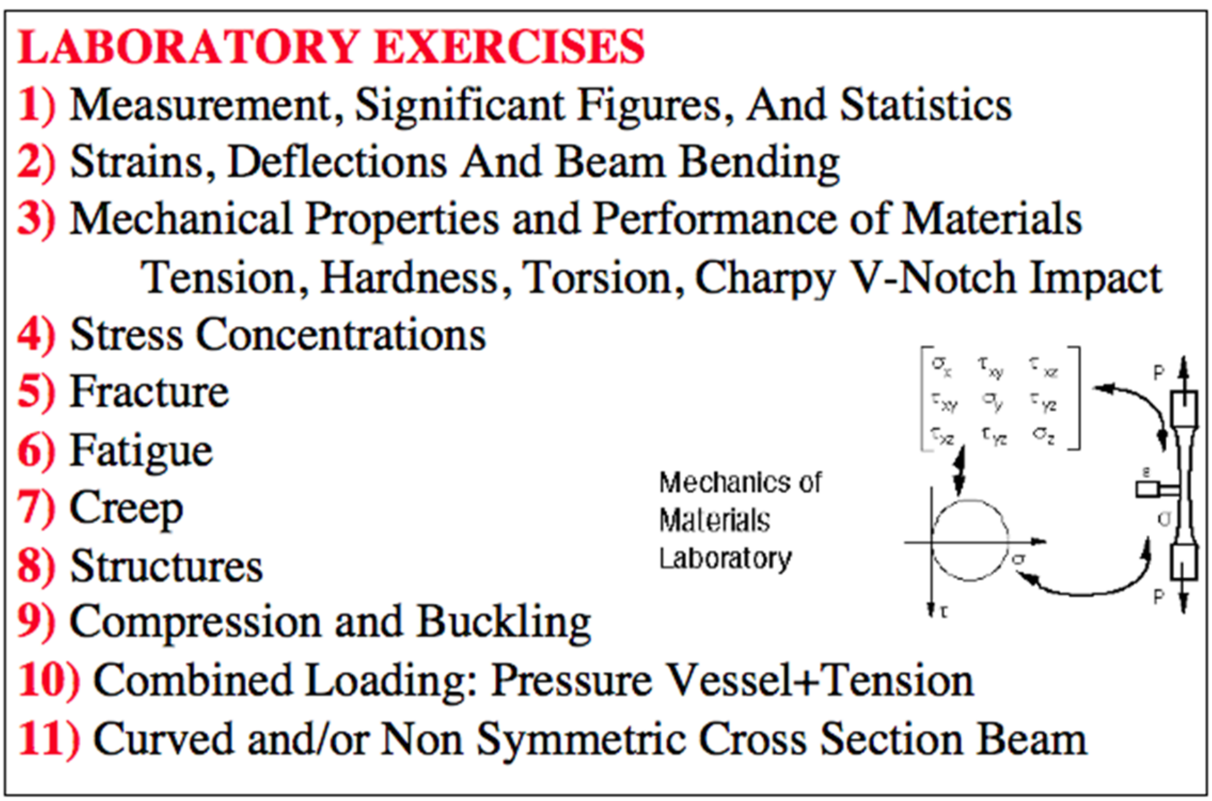

Figure 4 Experiential “do-say” laboratory exercises within MOML

MOML involves the application of fundamental mechanics of materials in "hands-on" laboratory exercises. The two pedagogical goals are 1) to "do" the exercises, observing and applying the aspects of mechanics of materials either learned in previous courses or introduced in MOML, and 2) to "say" in formal and informal laboratory reports how basic concepts were applied, analyzed and evaluated in laboratory exercises. The stated learning outcomes for MOML are as follows:

By the end of this course, the student will be able to:

1) List and explain applicable experimental methods for characterizing material and component behavior.
2) Compare (and quantify differences) measured experimental results and calculated theoretical values.
3) Predict component behavior using experimental test results and engineering formulae.
4) Analyze experimental data, theoretical models and their scalability to components.
5) Analyze (deduce) the inherent variability of materials subjected to multiple modes of loading and apply the results to component behavior.
6) Formulate a solution path for analyzing an actual multi-component structure using experimental, theoretical, and numerical tools/methods.
7) Evaluate the limits of structures by extending the experimental measurements using theoretical and numerical methods.

Structures Laboratory Exercise

Within MOML, there are two types of experiential laboratory exercise reports/exercises: in-lab pre-formatted reports and formal engineering laboratory reports. Both these types of exercises emphasize the hand-on aspects of the exercises by requiring students to examine, set up and operate apparati. In addition, teamwork is fostered by arranging students in groups to act as leaders, operators, recorders, and calculators. In the pre-formatted reports, students are not only guided through calculations using their measurement results but are asked both directed and open-ended questions to stimulate the analytical, synthetical and evaluative levels of their cognitive domain. In the formal laboratory reports, students are encouraged to work collaboratively on the analysis and interpretation, but ultimately each student must generate an individual laboratory report, thus stimulating the same cognitive domain levels, but uniquely.

The Structures laboratory exercise is the subject of this paper because it has been found to strongly reflect the "do-say" aspects of the active learning base of the cone of learning by incorporating all six levels of Bloom's taxonomy.

In this exercise, the question is posed "When is a truss not a truss?" in regard to a bicycle frame subjected to a static load. The overall purpose of this exercise is to the study the effects of various assumptions in analyzing the stresses and forces in an engineering structure using engineering mechanics, experimental mechanics, and numerical modeling. The learning outcomes are as follows:

By the end of this exercise, the student will be able to:

1) List the necessary assumptions and apply a simple truss analysis to a bicycle frame.
2) Apply an appropriate energy method to determine the deflection at a designated point in the bicycle frame using the results of the simple truss analysis.
3) Use strain gage conditioning equipment and dial indicators to experimentally measure relevant strains and deflections on an instrumented bicycle frame.
4) Apply appropriate transformation and constitutive relations to obtain stresses at strain gage locations.
5) Interpret results from a numerical model (finite element analysis) of the bicycle frame to extract relevant stresses and deflections.
6) Compare the analytical, empirical and numerical results and evaluate the appropriateness for each in describing the stress state and deflection of the bicycle frame.

Students are first asked to review what they know about truss structures including the assumptions of pinned joints, members that are uniformly, axially-stressed only, externally-applied forces at joints only. Several examples of truss structures (including bridges) are examined either directly or through photographs. Students are then asked to examine a bicycle frame and note the similarities between a truss and the bicycle frame: triangular sections and reaction loads at the axles. Next, the dissimilarities between a truss and the bicycle frame are discerned: lack of pinned joints and nonuniform, non axially-stressed members.

After making this comparison/contrast of a truss and a bicycle frame, students are asked to hypothesize that a bicycle frame is not a truss and, therefore, probably cannot be analyzed as such. Three methods are then employed to prove or disprove this hypothesis: analytical, experimental, and numerical.

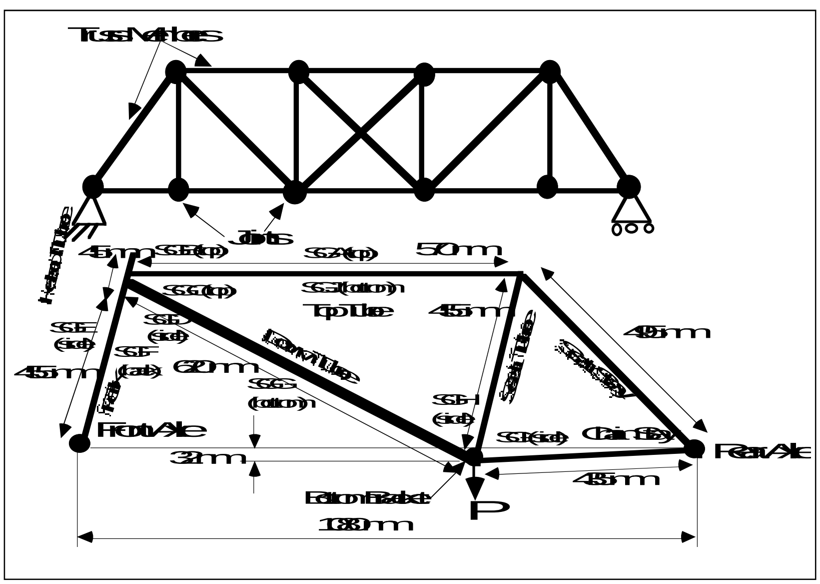

Figure 5 Comparison of truss and assumed lengths and angles of bicycle frame for truss analysis

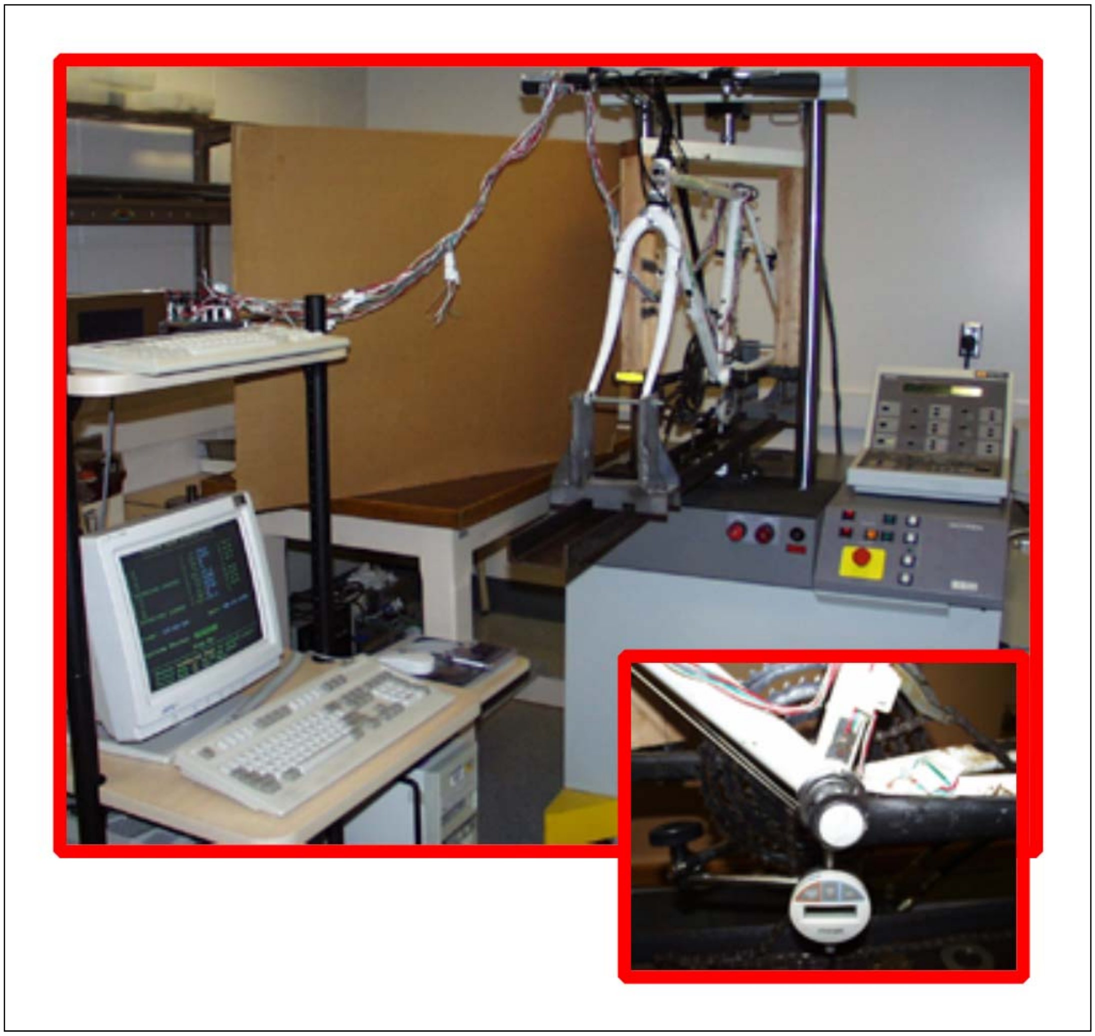

Figure 6 Experimental setup showing the strain-gauged bicycle frame mounted in a universal test frame (inset shows displacement measured at the bottom bracket)

Analytical: Similarities of a simple truss to the bicycle frame are noted. Assumptions regarding the reaction and loading points are made such that the resulting planar truss is statically determinant (i.e., b=2j+f-r where b=number of members, j=number of joints, f=special conditions, and r=number of reactions) and geometrically stable (det A=0 where A=matrix of direction cosines for the equilibrium equations). After the reaction forces are determined, the force in each member is determined using the assumed lengths and angles of each member and the appropriate truss analysis (see Figure 5). Finally, the unit load method is used to determine the deflection at a designated point (e.g., bottom bracket).

Experimental: The ten locations at which rectangular rosettes have been applied to the bicycle frame are identified (see Figure 6). Selected strain gages are connected to the conditioning equipment. A dial indicator is positioned at the same location on the bicycle frame as that designated for the unit load method. The outputs from the instruments are zeroed with no force applied to the frame. A load representative of a rider and equipment (50 to 80 kg) is applied to either the pedals or the seat and the strains and deflection are recorded. The load is removed and any changes in the zero points are noted.

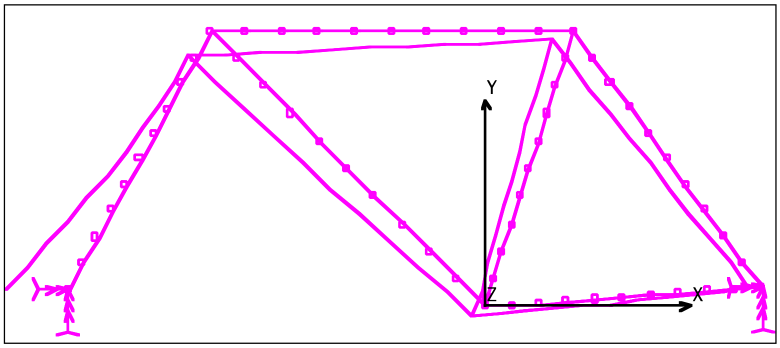

Figure 7 Numerical (FEA) model of bicycle frame in undeformed and deformed states.

Numerical: The results from a simple finite element model are made available through the course website. The 90 “pipe” elements (with dimensions similar to those for the relevant bicycle frame tube) are connected through 88 nodes in a linear elastic three-dimensional model (see Figure 7). Boundary conditions are applied to vertically and horizontally, but not rotationally, constrain the reaction points to approximate the experimental conditions. The results (i.e., elemental and nodal forces, stresses and deflections) in tabular and graphical form are made available in digital file format.

Once all three methods have been completed, the results are compared to ascertain whether the validity of the hypothesis that the bicycle frame is not a truss. Generally, students conduct the experiments and perform the analyses and interpretation of the results as small teams. However, each student must write an individual formal report containing the following sections: executive summary, introduction/objectives, description, results, discussion/conclusions, and appendices.

Assessment/Evaluation

The success of this “do-say” exercise in achieving the objectives and learning outcomes is assessed several ways: formal engineering report, targeted exam questions and discussions in a post laboratory recitation section. Evaluations of the success of the exercise occur through comparisons of grades for the Structures lab report to grades for other lab reports completed in MOML during the same academic period, feedback from student course evaluations and individual interviews with students. In the first three academic years since the Structures laboratory has been in place, approximately 165 students per year for a total of nearly 500 students who have participated in this exercise.

Assessment: Typically there are two to four formal engineering laboratory reports during the course of the quarter in MOML. Individual students generally score about ten percentage points greater for the Structures laboratory report as they do for the non-Structures reports. Exam questions directly aimed at the Structures laboratory have not been as straight forward to interpret, although students are generally able to connect the exam questions to the laboratory exercises. During the post laboratory recitation section, students are asked questions about the laboratory and are allowed to opine on the results and their interpretation. No formal assessment measures have been put in place for this part of the course although anecdotally, students express satisfaction with the flexibility of this lab exercise for analyzing and interpreting the results (i.e., this is not a “canned lab”).

Evaluation: Of the two to four formal engineering reports required per academic quarter, the mean scores for the non-Structures reports are in the 70 to 80% range. The mean scores for the Structures reports are in the 80 to 90% range. This difference in grades is directly linked to students' performing a more complete and in depth analysis and evaluation of the results of the exercise. Course evaluations completed by students are comprised of two parts: fixed questions for the broad range of questions requiring numerical answers (range of 1 (very poor) to 7 (excellent)) and fixed, but general, open-ended questions requiring written responses. Little information regarding individual laboratory exercises can be gathered from the numerical answers, however students often offer opinions on what contributed most to their learning. In this case, the Structures laboratory report is often cited as a positive experience. Finally individual interviews with students that specifically target the Structures laboratory exercise have been quite revealing. Comments such as, "fun," "most useful," "putting the pieces together," "pertinent," and "realistic" have been extracted from these interviews.

Conclusions

Experiential learning based on "do-say" active learning exercises has been shown to be beneficial in much aspect of engineering mechanics. A revision of the Mechanical Engineering curriculum resulted in a new experiential learning course, MOML "Mechanics of Materials Laboratory." Within this course a particularly successful activity has been the Structures laboratory exercise which allows students to determine the answer to the question "Is a truss by another name still not a truss?" in regard to a bicycle frame using analytical, experimental and numerical methods. Assessment and evaluation methods applied to this course and the Structures laboratory exercise, in particular, have validated the efficacy of the "do-say" active learning concept

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Biographical

Michael G. Jenkins is a Professor in Mechanical Engineering and Former Dean of Engineering at California State University, Fresno. He was the developer and coordinator of MOML "Mechanics of Materials Laboratory". He was the chair of the ME Departmental ABET subcommittee at University of Washington (UW) and is an advocate of the active learning and teaching philosophy per ABET EC2000. Prof. Jenkins is a registered professional engineer in Washington and is actively involved through leadership roles in national/international committees such as ASTM, ASME and ISO. Prof. Jenkins received his BSME from Marquette University in 1980, his MSME from Purdue University in 1982 and his PhD from the University of Washington in 1987. He worked 3 years at PACCAR Technical Center as an R&D engineer, 5 years at Oak Ridge National Laboratory as a development staff member, 12 years as faculty and associate chair at University of Washington, Seattle, 4 years as faculty and chair at University of Detroit Mercy before starting his position as faculty and dean at CSU, Fresno in 2007. His research and teaching interests include characterization of advanced materials (e.g., ceramics), experimental mechanics, data base development, cumulative damage mechanics, and probabilistic design and reliability.

Embedded Data Logging System

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Introduction

In the work place there come many times when one needs to compete alongside others to reach a goal or complete a project. In this course by formulating a real world project a relationship was established with a local company to improve existing products for them. Two groups of students were given the same problem statement and specifications for the development of an embedded system to measure and record environmental data including shock, vibration, temperature, and humidity. In addition to development and implementation of the project, another important outcome was to provide an opportunity to two different groups of students to compete on solving a problem and to provide an idea of what to expect in the future when entering the workforce.

Miscarriage of electronic products in distribution and during shipping is a major concern for every manufacturer. Manufacturers are interested to know and analyze the shipping condition when their products are damaged. The purpose of this project was to prototype an embedded monitoring data logger system to encompass into electronics products. In this research project, a small battery powered data logger equipped with microcontroller, data storage, networking connectivity and sensors was designed and implemented. The project was funded by Space Grant (NASA) and Undergraduate Research Grant (CSUF) and was done as a senior year project. Further, this project was implemented with collaboration and requests of a local company, Pelco, to be integrated into their DVRs and electronic camera systems. Damage to products such as DVRs or cameras is a serious problem, since defective products result in unnecessary time and money. The project was completed on time with hard work and team efforts. The team went through research; prototyping and final PCB design phases. Some of the components used to monitor the surrounding environment include: a triple axis accelerometer, a temperature sensor, and a humidity sensor. A portable power source provides adequate power to the device. A USB interface is used to read data from the microcontroller or vice versa and a JTAG is used for necessary programming. Also, an Ethernet port is used for remote monitoring. The final module is capable of logging temperature, humidity and acceleration at any desired interval and the saved data can be read via USB or Ethernet protocols. The above features will come in handy to control the physical condition of the electronic system products of Pelco in storage, transit, or distribution.

System Design Overview

The block diagram of the module is shown in Figure 1. The system is composed of seven main components: MCU, Temperature sensor, Humidity sensor, Accelerometer, External memory, USB and Ethernet ports. An accelerometer measures shock and vibrations, which provides information about the handling of the device.

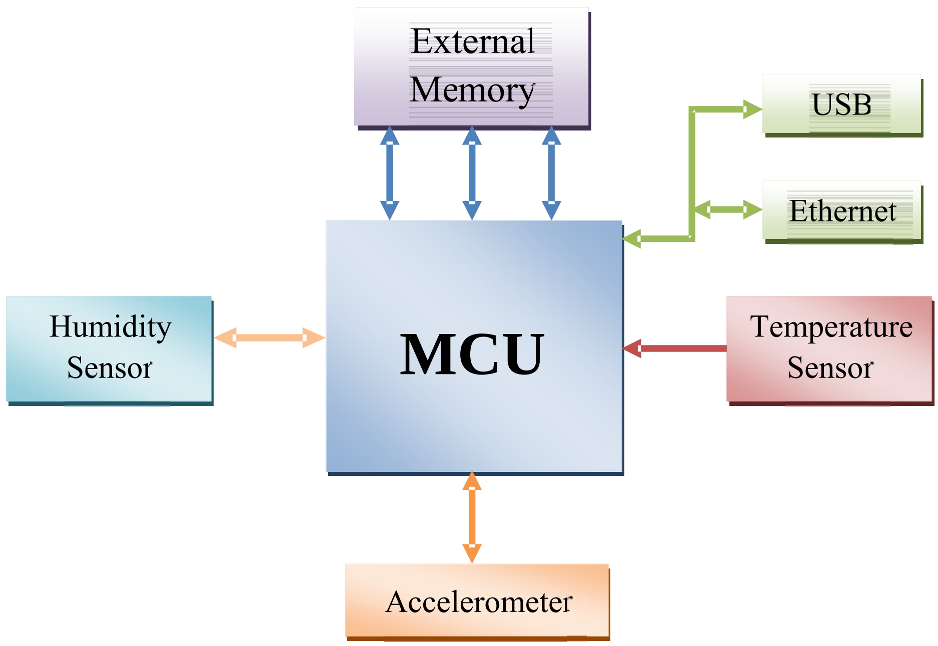

Figure1: System Block Diagram

The temperature sensor measures surrounding temperature and the humidity sensor measures the humidity. Data from these sensors is processed by the microcontroller and gets stored on an external memory. A real time clock is essential for time stamping the data. It was implemented on the microcontroller using an external 32.768 kHz tuning fork crystal and internal oscillator. The data obtained from this integrated circuit allow the user to view a detailed report of the surroundings at a certain instance in the shipping process. Three AAA batteries were used as a power source. The components used and the interfacing methods are briefly explained below.

MSP430F2274 by Texas Instruments[1] is the microcontroller used in this project. This is a low power 16-bit MCU which draws 0.7µA in standby mode and 270µA per 1MHz of clock speed. On the prototype, a JTAG header was used to program the MCU via a flash emulator. The same configuration was used in the final design. The MCU was programmed and debugged using the IDE called Embedded Workbench by IAR systems. All the programming was done in C language.

ADXL345 by Analog Devices[2] is the accelerometer that was interfaced with the MCU using SPI (Serial Peripheral Interface). Acceleration is measured by the change in capacitance when the suspended structure moves. It is designed to sense vibrations, shock along with dynamic and static gravitational forces. It is also capable of free fall and tap detection. Drivers were written for SPI protocol. The driver was written in the following sequence.

1. Pin initialization
2. Channel and communication Mode selection
3. Clock and clock divider selection

These were three main steps that were performed in order to initialize the SPI port on the MCU. These steps just set a channel for communication. The next step was to write the data sending and receiving functions which were straight forward.

LM20 by National Semiconductor[3] is the temperature sensor used. This device has an analog output so MCU's A/D converters are used to digitalize the output which then can be stored on external memory. The maximum output voltage of the LM20 is 2.5 V, which corresponds to about -55C°. The output can be converted to °C by applying equation (1).

$$T = -1481.96 + \sqrt{2.1962 \times 10^6 + \frac{(1.8639 - V_o)}{3.88 \times 10^{-6}}} \qquad (1)$$

HS1100LF by Measurement Specialties[4] is a relative humidity sensor. This is also an analog sensor; the change in capacitance is proportional to the change in humidity. One way to measure the frequency is to use the sensor as a variable capacitor with a 555 timer operating in astable mode. In this project, Timer A and Timer B were used for the frequency counting. Timer A was used to control Timer B's counting interval; after one second the value in Timer B's counter is supposed to be the incoming frequency. For example if the incoming frequency is 4000 Hz Timer B will count up to 4000 in 1 sec as it counts on every clock edge; hence the number in the counter will provide the frequency. Code was written to compare the measured frequency to a response look up table, shown in Figure 2.

RH (%)	0	5	10	15	20	25	30	35	40	45	50
Fout (Hz)			7155	7080	7010	6945	6880	6820	6760	6705	6650
RH (%)	55	60	65	70	75	80	85	90	95	100	
Fout (Hz)	6600	6550	6500	6450	6400	6355	6305	6260	6210		

Figure 2: Typical Response look-up table

NP5Q128A13ESFC0E by Nymonyx[5] was used as external memory (PCM).It offers 128Mb or 16 MB of storage and has more than 1,000,000 write cycles, with bit alterable write operations. SPI was used as the communication protocol. The entire memory can be read with just one read instruction. In order to write to the memory specific commands were executed in the following sequence:

Drive Chip Select Low

Send the Write Enable instruction (0x06)

Drive Chip Select High

Drive Chip Select Low

Send the Page Program instruction (this contains the 6 bytes write address and write method) Send the Data, Drive Chip Select High when done with data sending. One Page Program instruction allows 64 bytes to be written, to write the 65th byte one needs to reissue the Page Program instruction.

UART to USB: A UART to USB chip by FTDI was used in this project to obtain the data from the MCU using a USB cable. This was done because serial ports have vanished from laptops and PC's. A breakout board from sparkfun[6] was used for easier assembly. Ch. A of MSP430's USCI has two functions assigned to it. It can either work in asynchronous (UART) mode or in synchronous (SPI) mode. As stated above the USCI share some of the pins between SPI and UART mode. Code was written logically so that only one mode was selected at a time. A GPIO pin was used as data reading interrupt. Whenever one needs to read the data a push button can be pushed, which will generate an interrupt which makes MCU jump to the ISR. Interrupt flag reset is the first thing done in the ISR. After that the data is read from the memory and displayed on a PC via the UART to USB converter.

Xport by Lantronix[7] is a serial to Ethernet converter. It converts serial data to Ethernet packets which can be sent over LAN or Internet. This module will allow a company to read the data from any location. The Xport was connected in parallel with the UART to USB module, but it's not tuned on all the time. A switch is used to turn it on or off, as it draws a lot of current. When it is connected via an Ethernet cable it acquires its own IP address according to the host IP. It can be configured to have a static or Dynamic IP address; in this project it was configured to have a dynamic IP address. Software provided by Lantronix, called Device Installer, is used to find the Xport's IP once it is connected.

NTE1904 by NTE inc. was used as the voltage regulator for the whole circuit.NTE1904 has a very low dropout voltage of .45 Volts. It regulates the output to a stable 3.3 Volts with a maximum current drain of 1 A. For this project the power supply was made up of three AAA batteries with a total of 4.5 volts output. With this supply voltage headroom of 1.2 Volts is obtained, which means that the regulator will regulate the voltage until it drops below 3.3 Volts.

Software Modules

Voltage Sensing: Voltage measurement is necessary for issuing a flag when the battery voltage drops below a user defined threshold.MSP430's user guide revealed that there are several ADC10 channels which can measure the supply voltage. Once the supply voltage drops below 2 Volts a low voltage flag can be issued.

Real Time Clock (RTC): A real time clock is essential for time stamping the data. For simpler design a Software RTC was implemented on the MCU. Timer A of MSP430 was used to generate an interrupt after every second, this served as a time base. UNIX time counts the number of seconds elapsed since midnight proleptic Coordinated Universal Time (UTC) as of January 1, 1970.[8] The next step was to keep track of seconds. For this purpose an ISR (Interrupt Service Routine) for Timer A was written. In this ISR a variable called seconds was incremented. The conversion from UNIX time to normal time can be done with Excel by using the formula shown below:

Normal time = (A1 / 86400) + 25569.
When the result cell is formatted for date/time, the result will be in GMT time (A1 is the cell with the UNIX time). Adjustments can be made to get the correct time for specific time zones.

Unix Time	Standard Date	Standard Time	Temp(F)	% RH
1289615945	Friday, November 12, 2010	6:39:05 PM	69	50
1289615947	Friday, November 12, 2010	6:39:07 PM	69	50
1289615949	Friday, November 12, 2010	6:39:09 PM	69	50
1289615951	Friday, November 12, 2010	6:39:11 PM	68	50
1289615953	Friday, November 12, 2010	6:39:13 PM	69	50

Table 1: Conversion of UNIX time to Standard time

This conversion is done on a host computer which saves MCU's resources and enhances the battery life. The seconds variable was defined as a long integer which takes Four Bytes of memory. The highest unsigned number that can be represented in Four Bytes is FFFFFFFF or 4294967295 in decimal. This number corresponds to year 2106, which will come approximately 95 years from now. Therefore, four Bytes of memory space is enough to keep real time for almost a century.

Data Writing and Reading Module: Data writing and reading from the PCM are the two important aspects of this project. To make data writing efficient, buffers were used to store the data in MCU's RAM. Once the buffers accumulated a predefined number of bytes, data was then transferred from RAM to the PCM. An example for temperature and humidity is shown below:

Four Bytes of Time Stamp	One Byte of Temperature Data	One Byte of Humidity Data

PCB Design

A PCB is an essential part of any electronic circuit. For this project PCB artist was used to design and create a PCB. By using a PCB the prototype shown in Figure 3 was transformed to a smaller and efficient circuit. The final board is shown in Figure 4.

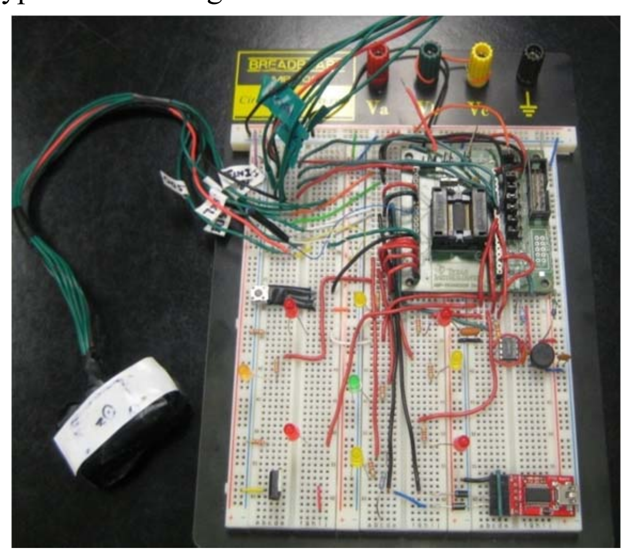

Figure 3: Prototype

Figure 4: Final Assembled PCB

Testing

Tests were conducted on the module to verify its operations. Tests included recording acceleration, humidity and temperature data to the memory and then reading them back on a PC.

Received Data:
t,x,y,z
1,0,-1,6
2,0,-1,7
3,0,-1,7
4,0,-1,6
5,0,-1,6
6,1,-1,7
7,1,-1,6
8,1,-1,6
9,1,-1,6
10,0,-1,6
11,-1,5,9
12,-4,1,5
13,-1,0,7
14,-2,-1,6
15,-2,-1,6
16,-2,-1,6
17,-2,-1,6

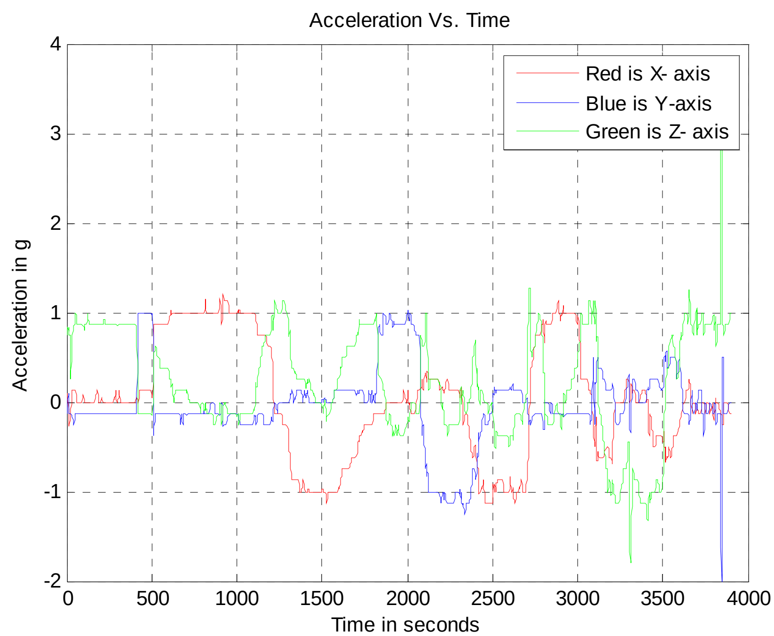

Figure 5: Analyzing acceleration data

Figure 5 above shows one method of analyzing the acceleration data. Data was stored in a text file with the help of an open source terminal program caller RealTerm. Once the data was saved to a file, it was then imported to MATLAB. The plot command in MATLAB was used to graph the data vs. samples. Here *t* does not represent time; instead it represents the sample number.

Unix Time(seconds)	Temperature in Fahrenheit	Relative Humidity in %
1289958521	78	40
1289958523	77	40
1289958525	77	40
1289958527	78	40
1289958529	83	40

Table 3: Temperature and Humidity along with time in seconds

The above shows the data collected from the module. It is displaying the temperature and humidity at a certain time. The time is indicated by the UNIX time, the temperature is shown in Fahrenheit, and the humidity is represented in percentage. When the temperature sensor was touched by a finger the temperature started going up as it can be observed from the table above. The data shown was first saved to the memory and then read back by pressing one of the switches, which generated a memory read interrupt.

Conclusion

Project management, problem solving techniques and basic interaction skills were an important learning experience for the groups. The positive effect of professional development with industry sponsored project is a kind of pedagogical that should be disseminated in the student learning outcomes. Another important educational outcome was the competition between the groups which brought a new level of innovation in teaching and learning techniques that is so conducive with what is practiced in industry.

The parts discussed in this report were used to build a module that is used to monitor the surrounding environment. This module meets most of the specifications stated by Pelco. The module consists of: a triple-access accelerometer, a temperature sensor, a humidity sensor, a USB to UART, a voltage regulator, and an Ethernet port. This way the module can detect, record, and send the surrounding condition data. By analyzing the conditions that each product is subjected to, Pelco will further improve the quality of their products.

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Accident Reconstruction: A Model-Eliciting Activity in Dynamics

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Abstract

Typical assignments in a traditional dynamics course often do little to motivate students or to give them an indication of how they would use the material in a future job situation. Many instructors are now attempting to provide motivational projects, hands-on demonstrations, and even laboratory assignments to increase understanding and motivation. To help provide motivation and real-world context in our dynamics course, we have implemented an Accident Reconstruction Model-Eliciting Activity (MEA).

MEAs originated in the math education community. They focus on the process of problem solving and model development, rather than just a final answer. The originators of MEAs propose six primary principles to develop new problems[1]. These principles support and encourage open-ended problems in a realistic engineering context. By requiring students to apply problem-solving and modeling skills, MEAs promote long term retention of concepts.

The Accident Reconstruction MEA asks student teams to create a new procedure that police in Sri Lanka can use when determining if a driver was speeding just prior to the accident. When first implemented, students were tasked with developing a step-by-step procedure, keeping in mind that the police were the end user/customer. Although students were free to create a computer program, the teams rarely did so. During the fall 2010 quarter, students were instructed to create an Excel file with a user's manual to perform the analysis. The paper will discuss student surveys, comparison of exam performance, responses on reflection exercises, and performance on the Dynamics Concept Inventory.

Introduction to MEAs

The Accident Reconstruction MEA was implemented in a Dynamics course at the California Polytechnic State University in San Luis Obispo. While the class is offered through the mechanical engineering department, it includes civil, aerospace, biomedical, and industrial engineers. This course is known for its appreciable difficulty level and represents one of the lowest passing rates for all of the mechanical engineering courses. One of the motivations behind using the MEA model is to improve understanding and passing rates for the course.

The goal of the Accident Reconstruction MEA and similar projects is to introduce students to problems with an engineering context. Professors have found that although a student may be able to demonstrate proficiency in solving traditional homework problems and calculations, underlying misconceptions may still exist in the material. By allowing students to develop models and practice problem-solving applications, these misconceptions can be exposed and corrected.

One of the ways to promote problem solving is through the use of MEAs, which were originally developed in the mid 1970's to understand how students studying mathematics develop and use problem-solving thought processes. Rather than focusing students towards a singular answer, MEAs encourage the development of a problem-solving strategy that can be generalized and reused in a variety of situations. More recently, MEAs have been expanded through a four-year collaborative research project between seven universities. The purpose of the research is the implementation of models and modeling as a foundation for undergraduate science, technology, engineering and mathematics (STEM) curriculum and assessments within the engineering domain[2].

When developing MEAs, the original creators proposed six principles[3,4] and characteristics of MEAs:

1. The Model-Construction Principle requires that the students come up with a procedure or model for explaining a "mathematically significant" situation.
2. The Reality Principle puts the problem in context and offers a client who needs a realistic engineering solution to a problem.
3. The Self-Assessment Principle enables students to analyze their problem solutions and revise their approach to open-ended problems.
4. The Model Documentation Principle requires students to create a mental model of their process in solving the problem. Documentation of their model and solution is often in the form of a memo to the client.
5. The Generalizability Principle asks students to develop models that other students (and the client) could easily use, and models that can be adapted to other similar situations.
6. The Effective Prototype Principle states that the concepts students must formulate, construct, and modify must be robust in terms of their applicability to their future academic and professional life.

Typical MEAs consist of open-ended projects that simulate real world problems and require small teams of students to develop problem-solving methods. These problems differ from typical homework assignments in length of time, access to information resources, number of individuals involved, and type of documentation required. Often the students address a fictional client when completing the MEA. This style is meant to better reflect typical scenarios that students will face in industry.

Accident Reconstruction MEA

The accident reconstruction MEA requires students to develop a model for reconstructing traffic accident scenarios to determine the initial speeds of the parties involved. In order to simulate a realistic engineering scenario, the problem was given in the form of a memo from the Inspector General of the Sri Lanka Police Department. The Police department is looking to update and modernize their services and needs assistance in developing a procedure to analyze traffic accidents. The MEA was inspired by a news article describing how U.S. Police forces have been assisting Sri Lankan officers in updating their protocols after the Sri Lankan Civil War. The use of a Sri Lankan client adds an international component to the MEA, and students must account for unfamiliar elements, such as the use of the metric system and drivers operating on the other side of the road.

During the first implementations of this MEA, four accident reports and a pre-read document were provided with the memo. Many of the cases are based on actual police reports provided by the Oceanside Police Department. The remaining reports are fabricated to represent realistic accident scenarios and were modeled after the provided reports. The pre-read document provided students with general information on accident reconstruction by forensic engineers and background information on the Sri Lankan police department. The memo specifically requests parameters that should be recorded at the scene of the accident and a step-by-step procedure for reconstructing the scenario. The four accident cases given to students are located in the appendix.

Before the Accident Reconstruction MEA was assigned, students were given three to four homework assignments and example problems involving vehicle accident reconstruction. This allows students to understand and practice how energy and conservation of momentum principles can be applied to traffic accident scenarios. For the MEA, students were divided into teams of four and were given one week to complete the assignment. In earlier implementations, students were allowed to email the professor during the week to request additional information not provided in the MEA such as crush factors and friction coefficients.

The first accident scenario, Case A, involved a single driver who loses control of the vehicle. The vehicle rolls on to its roof and skids for a given distance until hitting a stationary cement pole which brings the vehicle to rest. The accident report provides students with weather and road conditions during the time of the accident as well as the posted speed limit for that road. To accurately model this scenario, work-energy principles can be used to find the amount of kinetic energy lost during the skidding and impact. Different coefficients of friction should be used during braking and when the vehicle is skidding on its roof. The change in height of the center of gravity during the roll should also be accounted for. Unlike the other scenarios, crush factors must be used to model the collision of the vehicle and cement pole. The crush factors for this scenario were provided in a previous homework assignment.

In Case B, a sedan and a cement truck collide at a controlled intersection. The collision occurs as the cement truck is making a right turn (note that the cement truck and sedan would be driving in the left lane due to Sri Lankan traffic procedures). Students are told that the two vehicles stick and slide together after the collision. The lengths of vehicle skid marks are provided, allowing students to find the amount of energy lost when braking. Using work-energy principles, students are able to calculate the speed of the combined vehicles just after the collision. Since the directions of the vehicles are known both before and after the collision, conservation of momentum can be used through the impact to calculate the speeds of both vehicles before the collision. Finally, work-energy principles can be applied to the sedan to calculate its initial speed before it began to skid.

The third accident report, Case C, involves two vehicles in a head on collision. After the collision, both of the vehicles skid together. Impulse-momentum principles can be used through the collision. Since the accident takes place on the peak of a hill, the calculations are further complicated by changes in height. These changes and the presence of skid marks before and after the collision must be accounted for when performing energy calculations.

The final scenario, Case D, involves a collision on a highway. The collision occurs as one vehicle is merging onto the highway from the on-ramp. Using information provided on the directions that the vehicles are traveling prior to the collision as well as skid mark information, students can use energy and momentum principles to calculate the initial speeds.

During the initial implementations of the MEA, it was expected that some groups would utilize computers to assist them in problem solving. Since the same general equations can be applied to all of the situations, a single solver could be written in Excel or MATLAB to calculate the initial speeds in all scenarios. However, upon receiving the final solutions, it was found that nearly all groups solved all of the scenarios by hand. Additionally, it was noticed that most groups divided the scenarios among the members of the group and solved them individually, similar to typical homework problems. In order to promote collaboration amongst the group members and to also encourage use of computer tools, the initial problem statement was altered to require the use of an Excel program to calculate initial speeds. In doing so, the MEA was able to better reflect a more realistic engineering context with a generalized solution.

When implementing the MEA, the students use the first two accident scenarios to develop their models and computer programs. Afterwards, students are provided with the final two accident reports which were used to evaluate the computer models that the students developed. This allows students to assess their solutions for accuracy and plausibility. Additionally, students can see if their model needs to be expanded to include additional parameters. The memo used in fall of 2010 (with the required Excel program) is shown below:

Memorandum

To: Forensic Engineering Team

From: H. M. B. G. Kotakadeniya, Senior Deputy Inspector General of Police, Sri Lanka Police Service

RE: Traffic Accident Reconstruction Protocol

Priority: [Urgent]

Since 2003 your country has been providing assistance toward development and economic stabilization here in Sri Lanka. Relations have gotten even closer with the invaluable help we received following the devastating tsunami in 2004. As a result, we have been able to become an important figure in the fight against terror in South-Central Asia.

As you may already know, the Sri Lanka Police Service has recently launched a new programme to update and modernise the service we provide to the public. One key area for improvement is in the Traffic Police Division. This division was established in 1953 to assist in making decisions on traffic policies and implementing them. Every currently existing station maintains a traffic branch, but the growing number of drivers on the island and our intention to build new stations demand that we immediately improve our accident investigation protocol. I am charging you with the task of compiling a new computer tool for accident investigation that can be used in this division. At the moment the main focus of this task is to develop an Excel program for determining if a driver has violated the speed limit.

My officers will provide you a set of two abridged incident reports that are characteristic of typical accidents that we regularly investigate – please refer to our online site on for these reports. We are compiling an additional two reports that will also be provided to you at a later date. For legal reasons, sections of the reports have been omitted and the names of those involved have been replaced. In each report you will find a general description of the accident followed by more detailed information pertaining to possibly relevant parameters in the accident.

We request that you provide the following to our office by 9pm on October 18th: (1) an Excel program that we can use to estimate driver speeds for almost any accident scenario, (2) a User's Manual that describes the basic principles used in your calculations and that provides instruction on how to use the program , (3) instructions on what parameters the officers should collect at the scene, (4) your detailed analysis on how you used your program to solve all four accidents, (5) hand calculations that verify your program results for the first two accident scenarios, and (6) a cover memo that discusses your conclusions for each of the accident scenarios and if you think we should prosecute the drivers. This memo should also include a discussion of how confident you are in the calculations given the uncertainty in some of the values used in your analysis (e.g., our friction coefficients can vary by 10% in many cases).

I am certain that your team will exceed our expectations.

H. Kotakadeniya

H. M. B. G. Kotakadeniya

By creating a computer model, students have the capability of seeing how the solution changes using different values for coefficients of friction and crush factors. Since students are asked to make decisions as to whether or not the driver should be prosecuted, it was hoped that students would use these programs to evaluate the certainty of the calculations. In fact some of the solutions to the accident scenarios were designed to be highly sensitive to these values, with outcomes that could change if the coefficient of friction values were altered by 10%.

The following table reflects how the Accident Reconstruction MEA meets the six principles using the assignment on the previous page:

TABLE 1
THE ACCIDENT RECONSTRUCTION MEA DESIGN PRINCIPLES

Design Principle	**How the Accident Reconstruction MEA meets the design principle**
Model Construction	Each group of students is required to develop an analytical procedure for traffic investigators to reconstruct traffic accidents.
Model Documentation	Teams submit a memo explaining their methods and procedure for accident reconstruction. Additionally, students provide the Excel program to calculate initial speeds along with a set of instructions for using the program.
Generalizability	The procedure developed is applicable to each of the provided scenarios and can encompass a wide range of traffic accidents. The computer program should be capable of handling a variety of inputs.
Effective Prototype	The reconstruction procedure requires the use of work-energy and conservation of momentum principles.
Reality/Personal Meaningfulness	The MEA applies dynamics concepts to a realistic situation. The Sri Lanka police department has asked the engineering team to develop a procedure to determine the initial speeds of vehicles involved in collisions. Work energy and conservation of momentum principles are used by actual accident reconstruction experts for determining initial vehicle speeds.
Self Assessment	Students are able to validate their models against additional accident scenarios and homework problems.

Misconceptions

MEAs are valuable tools in evaluating students' thought processes and can often identify common misconceptions. For the Accident Reconstruction MEA, it was found that many students misidentified variables as vector or scalar quantities. Most often, students failed to recognize momentum as a vector and attempted to solve equations without splitting the equations into components. Similarly, many students treated energy as a vector quantity rather than a scalar. In some cases, students also attempted to conserve energy instead of momentum through an impact. However, in one interesting report, students conserved energy through the impact but provided an explanation for doing so. Since energy would be lost in the impact, the vehicles calculated initial velocity would be smaller than its actual velocity. In this case, the students felt that this was a more conservative approach for calculating velocities and would be easier for the Sri Lankan police officers to implement.

Evaluation

Student feedback was obtained during the fall of 2010 for the Accident Reconstruction MEA in the form of survey questions and open ended comments. This feedback followed the first implementation of the Excel portion of the assignment. Many students described the Accident Reconstruction MEA as helpful in learning and reviewing the material. Most of the negative feedback was related to the Excel portion of the assignment. Students described the program as "tedious and difficult" and "time consuming".

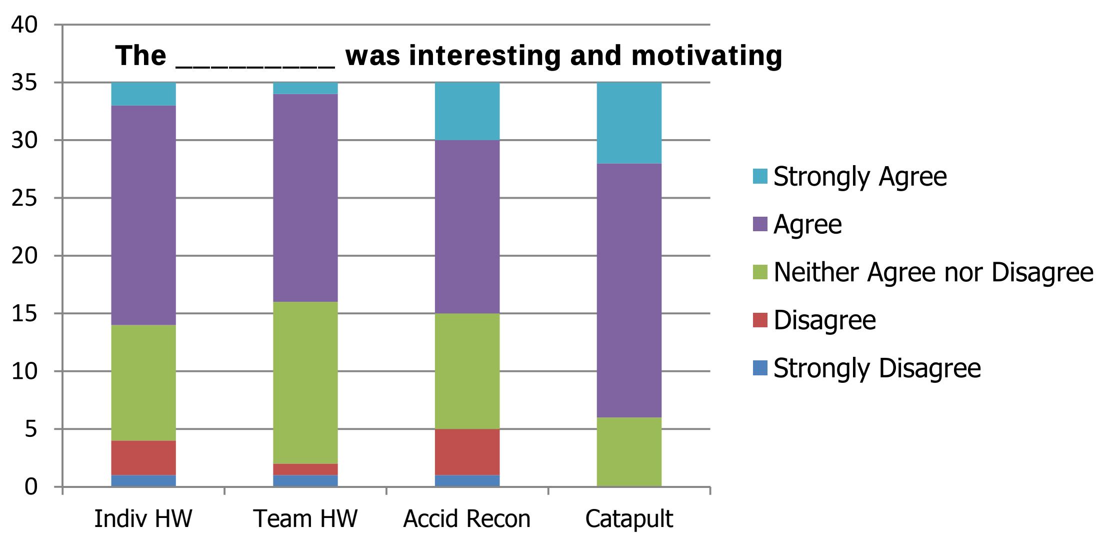
These complaints seem to stem from unfamiliarity with Excel and programming in general. Students are often resistant to using new and untried tools, and this MEA could provide more incentive for developing these skills. In future implementations, student concerns could be addressed in multiple ways. Before the MEA is assigned, the professor could make smaller Excel assignments as homework problems. This would allow students to become more familiar with Excel before the MEA. Also, an example scenario could be given to students as a tool to verify their programs. In the reported implementation, students were given accident reconstruction homework and example problems prior to the MEA which could have been used for verification. Another option is to simplify the types of scenarios in the MEA. In each of the cases, students are given slightly different information which is used to calculate initial velocities. By streamlining the solving process, students could more easily create a robust program. However, this solution may be undesirable since it reduces the amount of experience students receive when working with momentum and energy principles.

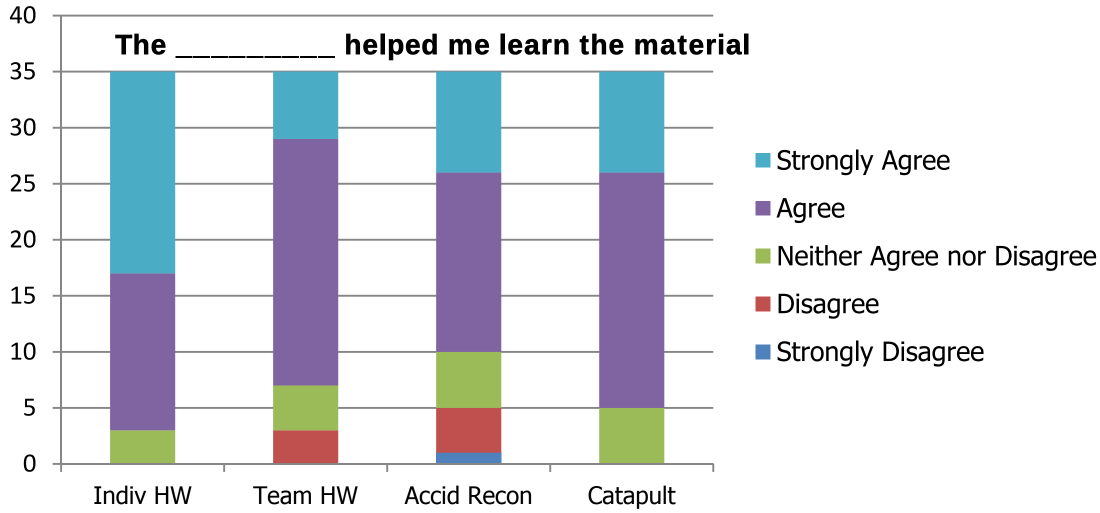
Subjective Assessment of Different Class Components

In addition to the Accident Reconstruction MEA, classes also included individual homework assignments, team homework assignments and a Catapult MEA[5]. The individual homework assignments were completed outside of class and consisted of traditional homework problems. For team homework assignments, each student is assigned a letter, usually ranging from "A" to "D." Four homework assignments are given, also labeled "A" through "D." Each student completes the homework assignment corresponding to their letter. During class, students collaborate in teams of four (each team comprises of every letter) and each student explains their homework assignment to the team. The Catapult MEA[6] is assigned towards the end of the quarter. In this MEA, the curator of the Peterborough Museum in England requests help from the student teams to predict launch distances in catapults for an upcoming catapult competition. Scale model catapults are given to the students, who then decide which measurements to take and how to model the different components of the catapult. Students are able to test their engineering models during a launch competition where they attempt to hit a small picture of their instructor with a raw egg.

At the end of the course, students complete a survey which evaluates the course components. This survey allows for comparison of student opinions of the different tools used throughout the quarter. Results for two questions from fall of 2010 are shown in Figure 1. As can be seen by the results, most students felt that the Accident Reconstruction MEA helped them learn the material. About half found the assignment motivating. Overall the Accident Reconstruction MEA appeared to perform slightly better than the team homework in terms of student opinion.

FIGURE 1
SURVEY RESULTS





In addition to the questions regarding the various components of the course, the survey also asked the students to rate how well the course improved specific skills. These questions are related to the ABET criteria and can be used to help evaluate the course's overall effectiveness. Of the eighteen ABET survey questions, fourteen of the most relevant to dynamics are listed below in Table 2. Note that the data in the table represents percentages of total students in the class and not actual numbers of students.

TABLE 2
ABET SURVEY RESULT COMPARISON
Percentage of students in MEA sections (n=35) and Traditional sections (n=124)

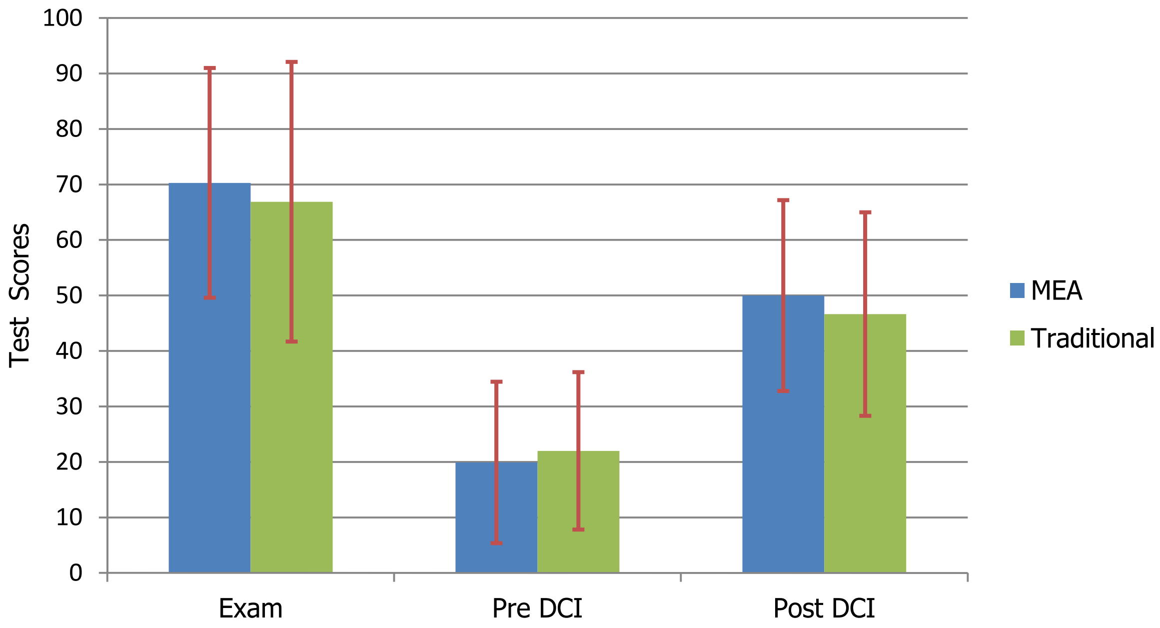
This course has improved my:		Not at All (%)	Very Little (%)	Some (%)	A Lot (%)	A Great Deal (%)
1. Ability to use math concepts to solve engineering problems.	MEA	0	0	34	31	34
	Traditional	2	1	23	40	33
2. Ability to use engineering concepts to help solve problems.	MEA	0	0	17	37	46
	Traditional	4	4	10	35	48
3. Ability to use physics concepts to help solve engineering problems.	MEA	0	0	3	34	63
	Traditional	3	2	14	36	44
4. Ability to design an experiment to obtain measurements or gain additional knowledge.	MEA	0	9	34	43	14
	Traditional	59	19	14	3	5
5. Ability to analyze and interpret engineering data.	MEA	0	6	38	41	15
	Traditional	19	15	38	19	10
6. Ability to design a device or process to meet	MEA	0	3	46	34	17

a stated need.	Traditional	50	17	23	7	3
7. Ability to function effectively in different team roles.	MEA	3	6	34	46	11
	Traditional	60	16	17	2	4
8. Ability to formulate and solve engineering problems	MEA	0	0	20	43	37
	Traditional	4	5	15	38	38
9. Knowledge of professional and ethical responsibility.	MEA	9	26	46	14	6
	Traditional	54	24	13	4	5
10. Ability to write reports effectively.	MEA	6	14	57	17	6
	Traditional	90	5	3	0	2
11. Ability to make effective oral presentations.	MEA	74	17	6	0	3
	Traditional	92	2	2	0	3
12. Knowledge of the potential risks and impacts that an engineering solution may have.	MEA	6	23	37	31	3
	Traditional	36	27	25	6	6
13. Ability to apply knowledge about current issues to engineering related problems.	MEA	31	23	29	14	3
	Traditional	65	19	12	2	2
14. Appreciation of the need to engage in life-long learning.	MEA	9	11	37	31	11
	Traditional	15	23	26	19	18
Averages:	MEA	10	10	31	30	19
	Traditional	40	13	17	15	16

While many of the traditional course objectives for dynamics (e.g., "Ability to using engineering concepts to solve problems") are similar, there are many noticeable differences in student opinion between the two styles. For example, most students from the MEA formatted classes found that the course improved their ability to work in teams "some" or "a lot" versus students in traditional courses who mostly answered "none at all." The MEA class also saw significant improvement in design, writing reports, current issues, and knowledge of professional and ethical responsibility. As can be seen from the last row in Table 2, students tend to report greater improvements for measured metrics in MEA formatted classes than traditional classes.

In order to evaluate the merit of using MEAs in dynamics, it is important to compare the grades of those sections using MEAs to the sections not using MEAs to ensure that grades were not lower for the MEA sections. During the fall of 2008, five of the eight dynamics sections implemented MEAs throughout the course, while the remaining sections followed a more traditional teaching style. In addition, students in each section were given the Dynamics Concept Inventory (DCI) [7] to evaluate their learning throughout the course. The DCI is a multiple choice exam containing conceptual questions that is given at the beginning and end of the course. Figure 2 shows the results of the exam and DCI quizzes with standard deviations.

FIGURE 2
EXAM SCORE COMPARISON



The figure shows little difference between the exam scores for the sections. A t-test was performed with a p-value of 0.077, which indicates no statistical difference between the sections (although the average final exam score was slightly higher for the MEA style classes). On the DCI, MEA sections experienced an overall normalized gain of 29.6% compared to 21.1% for traditional sections.

Conclusion

The use of inductive and active learning techniques is not new in engineering education. Model-Eliciting Activities provide a framework to help students develop their problem-solving processes, attack dynamics problems with engineering context, and learn to develop skills beyond just technical content. Although some (including the students themselves) might argue that the MEAs take away from lecture time or detract from students' ability to tackle traditional homework style problems, the data presented here do not support such a claim. Students in the MEA based class have shown significantly greater gains on the DCI than traditional lecture courses and slightly higher (although not significantly different) scores on the final exam. More importantly, the gains on additional skills related to ABET Criterion 3: Student Outcomes are much higher for the students completing the MEAs than for those who are not. We would also argue that by providing engineering context and familiar applications for the students, long term retention should be better when using the MEAs.

There are some hurdles to developing and implementing MEAs. It is difficult to develop MEAs that are challenging, within the scope of the class, and that meet the six principles. We have experimented with different implementations for the Accident Reconstruction MEA, and feel that the latest rendition is an improvement over the non-Excel version from previous quarters. In future quarters we may try to simplify the programming somewhat, but still want students to gain some experience in programming and in creating a generalizable solution. Another challenge is that the MEAs are not always popular, particularly in a fundamental course such as dynamics. Some students complain that they should not be writing memos in such a difficult course, and that time might be better spent elsewhere. One student remarked, however, “I will remember doing these projects like you said I would and I will forget doing the textbook problems,” and another that “making one program to work four accidents did connect the different concepts.” As we become more adept at developing the MEAs, they should become even better tools for improving student learning and motivation.

Acknowledgments

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Brian Self has been a professor at Cal Poly for the last five years. Before that, he taught at the Air Force Academy for seven years. He is the ASEE Campus Rep and served as the Zone IV Chair from 2008-2010. Besides his pedagogical research, Dr. Self is actively involved in aerospace physiology and biomechanics research. He has worked extensively to involve undergraduates in his research, taking students to present at national and international conferences. By involving students in solving ill-defined projects and problems that don't have a "correct answer," Dr. Self hopes to further advance their intellectual curiosity and problem solving skills.

Appendix

SRI LANKA POLICE DEPARTMENT MAJOR ACCIDENT INVESTIGATION TEAM

DATE OF INCIDENT	TIME	NCIC NUMBER	OFFICER I.D.	NUMBER
April 29, 2006	0422	3710	1120	06-015741

INTRODUCTION

This traffic collision occurred on Saturday April 29, 2006, at approximately 0422 hours. This traffic collision occurred on Pallamadu Rd, within the City of Colombo.

The collision involved a 1994 white Lincoln Continental driven by [redacted], henceforth referred to as Driver A.

The Lincoln was traveling northbound on Pallamadu Rd in the number 1 lane of travel at an unknown speed when the driver somehow lost control of the vehicle. The vehicle rolled over onto its top side in the number 2 lane of travel and proceeded to skid 70 meters on the asphalt roadway. It then hit a stationary cement pole on the side of the highway.

Driver A received minor injuries to the arms and head by broken glass and was treated on the scene by emergency personnel.

Released Per
Public Records
Act Request

SCENE :

Section omitted.

Weather Condition

The following weather conditions were noted at Colombo Airport. The airport is located about ¼ mile from the scene.

Time	Temperature	Dew Point	Humidity	Pressure	Visibility	Wind	Conditions
0352	66.8° F	64.7° F	81%	29.95 in	8 miles	Calm	Clear
0452	66.2° F	64.3° F	83%	29.96 in	8 miles	Calm	Clear
0552	65.7° F	60.2° F	92%	29.95 in	8 miles	3.2 mph NNW	Clear

Traffic Control

The posted speed for the road in the area of this collision is 75 km/h. The speed limit is clearly posted for both sides with Type R 75 KM/H speed limit signs. The speed limit was established by a traffic engineering and speed survey.

VEHICLES

Vehicle One (1994 Lincoln Continental)

Description

Year:
Make:
Model:
License: [redacted]
VIN:
Engine:
Transmission:
Color:
Type:
Weight:
Length:
Height:
Width:
Center of gravity: 61 cm (

Damage Description:

Front: Minor to moderate damage was sustained to the front right portion of V1. The front panel had a deflection of approximately 13 centimeters.

Right: Minor to moderate damage was sustained to this portion of V1. This damage consisted of scrapings where V1 was in contact with the road and broken side windows.

Left: I did not observed any damage to this portion of V1.

Rear: I did not observed any damage to this portion of V1.

Roof: Moderate damage was sustained to the roof of V1 but the average height of V1 remained unchanged.

INTRODUCTION

This traffic collision occurred on Saturday June 24, 2006, at approximately 0445 hours. This collision occurred within the intersection of Route A4 and Benet Rd, within the incorporated City of Colombo.

This collision involved a 2006 Acura TSX (V1) and a 2004 Ford Sterling Cement Truck (V2). The Acura was driven by [redacted], henceforth referred to as Person 1. The Ford was driven by [redacted], henceforth referred to as Person 2. The passenger in the Acura, seated in the front left seat, was [redacted].

The Acura was traveling eastbound on Route A4, in the number two lane of travel. The Ford had just entered the intersection, from the right turn lane, southbound Benet Rd to westbound Route A4. At impact, the Ford was in second gear. Maximum speed for a vehicle of this size in second gear is 8-13 km/h. This data can be supported by several case studies from the American National Highway Traffic Safety Administration and other related studies involving vehicles of this size. Witnesses indicated that the Ford partially through its turn when it was struck by the Acura.

PHYSICAL EVIDENCE

I documented the scene, walking from east to west. On the south side of Route A4 in the number two lane of eastbound traffic, I noticed skid from V1. This skid was measured by a roll meter with a distance of 20 meters. An additional 1.5 meters of skid was within the intersection, caused by the two vehicles sliding together. The skid was found to be at an angle of 130° from North in the Southeast direction ±5°. This evidence leads me to believe that P1 noticed V2 turning in the intersection and applied his brakes in a "Panic" situation.

At the collision scene, there was evidence of V l and V2's impact within the intersection. V1 was still impacted with the front right tire of V2. There was a mixture of engine fluids, vehicle parts, and glass. Using marking paint, I painted both V1 and V2 in their original positions before they were moved by tow trucks.

An interior inspection of V2 showed that it was "locked" in second gear and even when depressing the clutch, I could not remove the vehicle out of second gear. The tow driver had to manually unlock the transmission to move V2.

SCENE:

Section Omitted

Weather Conditions

The following weather conditions were noted at the Colombo Airport. The airport is about 1/4 mile north of the collision scene.

Time	Temperature	Dew Point	Humidity	Pressure	Visibility	Wind	Conditions
4:52 AM	64.9° F/18.3° C	61.0° F/16.1° C	87%	29.95 in/ 1014.1 hPa	4.0 miles/ 6.4 km	3.5 mph/ 5.6 km/h WWS	Overcast
5:52 AM	64.9° F/18.3° C	61.0° F/16.1° C	87%	30.00 in/ 1015.8 hPa	4.0 miles/ 6.4 km	8.1 mph/ 13.0 km/h SSE	Overcast
6:44 AM	66.2° F/19.0° C	62.6° F/17.0° C	88%	30.01in/ 1016.1 hPa	3.0 miles/ 4.8 km	3.5 mph/ 5.6 km/h North	Overcast

Traffic Control

The intersection of Route A4 and Benet Rd is controlled by a four way electrical signal system. During this investigation, I observed the signal phase from all four directions and found them to be working properly. The posted speed limit for Route A4 is 85 km/h. The speed limit is clearly posted for both east and westbound traffic with Type R 85km/h speed limit signs. The speed limit was established by a traffic and engineering survey.

VEHICLES

Vehicle One (V1, 2006 Acura TSX)

Description

Year:	2006	Engine:	2400cc 205 hp
Make:	Acura	Transmission:	5 speed Automatic
Model:	TSX	Color:	Blue
License:		Type:	2 Door [redacted]
VIN:	[redacted]	Weight:	1476.9 kg

Damage:

Front: The damage sustained to this portion of V 1 consisted of the entire front bumper being removed from the vehicle. The right side headlight assembly was completely broken out. An inspection of the broken headlight assembly, with the exposed headlight bulb filament, showed signs of oxidation and melting of the filament. This evidence showed that P1 had the headlights of V1 in the "On" position. The hood and right quarter panel was crumpled and dented. V1 had also expelled some of its engine fluids, i.e. Radiator fluid, oil, brake fluid.

Right: The only damage sustained on this side of V 1 was the front right quarter panel. This damage consisted of the quarter panel being dented and crushed.

Left: Besides slight crumpling and warping to the front left quarter panel, no other damage was sustained to this side of V1.

Rear: I did not observe any damage to this portion of V1.

Roof: I did not observe any damage to this portion of V1.

Vehicle 2 (V2, 2004 Ford Sterling)

Description:

Year:	2004	Engine:	Mercedes MBE 4000 450
Make:	Ford	Transmission:	8LL
Model:	Sterling	Color:	White
License:		Vehicle Type:	3 Axle Short Pour Cement Mixer [redacted]
VIN:		Weight:	

Damage:

Front: No visible damage had occurred to this side.

Left: No visible damage had occurred to this side.

Right: Besides the front right wheel assembly being broken, with several air and fluid lines broken, no other visible damage occurred to this side.

Rear: No visible damage had occurred to this side.

INTRODUCTION

This traffic collision occurred on Friday June 20, 2006, at approximately 0518 hours. This traffic collision occurred on Jawatte Rd, within the City of Colombo.

The collision involved a 1999 red Nissan Super Saloon driven by [redacted], and a 1994 black Ford Fiesta driven by [redacted].

The Nissan was traveling northbound on Jawatte Rd up a 7% grade. As the Nissan reached the top of the grade it collided head on with the Ford which was traveling southbound. The road north of the collision point, on which the Ford had been traveling, had a 0% grade. After impact, both vehicles slid together with locked wheels 5.8 meters down the hill.

Prior to the accident, a third driver reported that the Nissan was travelling approximately 18 - 25 km/h. The officer then left to respond to another incident on Kelaniya Rd.

Physical evidence at the scene indicated that the driver of the Ford was aware that he was about to impact Nissan. Wheel locked skid marks just prior to the collision were measured to be 9.4 meters in length and matched the tire pattern of the Ford. Roadway conditions at the time of the accident were slightly wet.

The driver of the Nissan was killed instantly. The driver of the Ford was transported via ambulance to Colombo Hospital received for treatment, then died later from his injuries.

SCENE :

Section omitted.

Weather Condition

The following weather conditions were noted at Colombo Airport. The airport is located about 3.2 km from the scene.

Time	Temperature	Dew Point	Humidity	Pressure	Visibility	Wind	Conditions
0452	19.3° C	18.2° C	81%	760.7 mm H_20	12.9 km	Calm	Light Rain
0552	16.8° C	17.9° C	83%	761.0 mm H_20	12.9 km	Calm	Foggy
0652	18.7° C	15.7° C	92%	760.7 mm H_20	12.9 km	5.1 km/h NNW	Foggy

Traffic Control

The posted speed for the road in the area of this collision is 40 km/h. The speed limit is clearly posted for both sides with Type R 40 KM/H speed limit signs. The speed limit was established by a traffic engineering and speed survey.

VEHICLES

Vehicle One (1999 Nissan Super Saloon)

Description:

Year:	Engine:	2200cc V4	
Make:	Transmission:	5 speed Manual	
Model:	Color:	Red	Super S
License:	Type:	4 door	[redacted]
VIN:	Weight:	1225 kg	

Damage Description:

Front: There was moderate to severe damage to this portion of V l. There was crumpling and creasing to the hood and sub-frame, along with breaks to the plastic front grill. Both headlights were broken out. An examination of the broken bulbs showed oxidation and melting to the filament. This indicated that the headlights were in the "On" position at the time of this collision. Some of the engine fluids (oil, coolant, brake fluid, etc.) had spilled onto the roadway at the collision scene.

Right: V1 sustained no visible damage to this end.
Left: V1 sustained no visible damage to this end.
Rear: V1 sustained no visible damage to this end.
Roof: V1 sustained no visible damage to this end.

Vehicle Two (1994 Ford Fiesta)

Description:

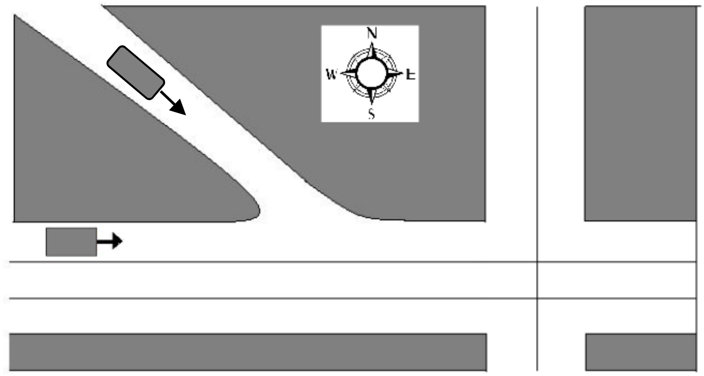
Year:	Engine:	
Make:	Transmission:	
Model:	Color:	
License:	Type:	[redacted]
VIN:	Weight:	

Damage Description:

Front: V2 sustained major damage to the entire front side from of the impact with V1. The center of the grill bumper area was completely crushed and destroyed. No evidence of oxidation or melting of the headlight filaments could be found. This indicates that the headlights of V2 were in the “Off” position at the time of impact.

Right: V1 sustained no visible damage to this end.
Left: V1 sustained no visible damage to this end.
Rear: V1 sustained no visible damage to this end.
Roof: V1 sustained no visible damage to this end.

INTRODUCTION



On Thursday, July 21, at 0300 hours, a traffic collision occurred on the junction of B79 and B243

A 1996 Honda Accord (V1) driven by [redacted] and a 1998 Ford Focus (V2), driven by [redacted] were the two vehicles involved in this collision. These drivers will be henceforth referred to as Person 1 and Person 2, respectively.

V1 was traveling eastbound on B79when it struck V2.

Person 2 was transported to a hospital to be treated for major injuries. Person 1 was treated for minor injuries on-site.

Based on the statement of Person 1, he had been driving under the speed limit when he suddenly was struck by Vehicle 2, and claims that Vehicle 2 suddenly veered across the merging lane. He states he has no recollection after that. Person 2 claims he was slowly merging into eastbound traffic, when Person 1 slammed into him. No pre-collision data was recorded for Vehicle 2. The figure above shows the area in which the collision occurred.

PHYSICAL EVIDENCE

No skid marks were present for the vehicles before the impact zone. The highways merge at an angle of 33°. The post-collision skidmarks measured to be 80m for Vehicle 2 at an angle of 80º from North, in the Northeast direction. The post-collision skidmarks measured to be 100m for Vehicle 1, at an angle of 135° from North, in the Southeast direction. Both of these skid distances were measured from the impact zone to the final location of the vehicles. The posted speed limit for both roads is 100km/h.

Roadway Description

Section Omitted

VEHICLES

Vehicle One (V1, 1995 Honda Accord)

Year:	1995
Make:	Honda
Model:	Accord EX
Color:	Green
License:	[redacted]
VIN:	[redacted]
Engine:	2700cc C27
Transmission:	4 speed automatic
Weight:	1295 kg

Damage Description

Front:

V1 sustained heavy damage to the front driver’s side.

Left:
Major damage was sustained on this side. Driver's-side door deflected at least a half-foot inwards.

Right:
Minor Dents and Scratches.

Rear:
Various scrapes and dents.

Vehicle Two (V2, 1998 Ford Focus)

Year: 1998
Make: Ford
Model: Focus
Color: Black
License: [redacted]
VIN: [redacted]
Engine: 1400cc Zetec-S
Transmission: 5 Speed manual
Weight: 1364kg

Damage Description:

Front:
Heavy damage was sustained to the entire front fender of V2. Driver side door crushed; driver side fender missing.

Left:
Various scrapes and dents.
Right:
Crushed appearance to all of right of vehicle – windows broken. Various scrapes and dents.

Rear:
Various scrapes and dents.

MALT PREPARER'S NAME	I.D. NUMBER	DATE	REVIEWER'S NAME	DATE
A. Ahubudu	1120	4/29/06		

Vehicle Accident Reconstruction Project

Background:

* Sri Lanka Police Department plans to set up police stations in recently captured areas
Saturday, September 13, 2008, **6:23** GMT, ColomboPage News Desk, Sri Lanka.

Proceedings of the 2011 PSW American Society for Engineering Education Zone IV Conference

Sept 13, Colombo: Sri Lanka Police Department has planned to set up police stations in recently captured areas and the territories to be freed from Tamil Tiger rebels, police chief, Inspector General Jayantha Wickramarathna announced.

The Police chief said that a large number of new police officers would be needed to man these new police stations that would be set up from Mannar to Mullaitivu. New recruitment has already commenced amidst positive response from the society, he said. The Inspector General of Police revealed these facts at a function held in Colombo yesterday to launch a programme to improve the productivity of the police service by 2009.

Excerpt from Introduction to Forensic Engineering by Randal Noon

Vehicle Accident Reconstruction

The reconstruction of vehicle accidents can be a very difficult task. In most cases, the engineer will be asked to reconstruct the events of an accident long after the accident has occurred. Sometimes, the actual accident scene will be prohibitively far away from the engineer or will have changed by the time he is given the reconstruction assignment.

Relying upon the often conflicting information provided by witnesses or the accident participants can be confusing and misleading. Often, the witnesses will report their own conclusions and opinions instead of objective observations; sometimes the accident participants will knowingly or unknowingly lie about the events. Under these circumstances, obtaining factual information with which to work can be trying.

However, the engineer will usually have the following reasonably objective information available to him at the outset:

1. **The police accident report.** The police report will contain the usual basic Identification information of the accident participants. It will also note the position of the vehicles after the accident as found by the police, the location of skid marks, the point of impact, the general layout of the scene, weather and conditions data, and the general travel pattern of the vehicles before the accident.
2. **Photographs of the damaged vehicles.** This is usually available from the insurance companies involved or their adjuster agents. They are used in evaluating insurance compensation to the accident participants.

The engineer may be asked to provide information or opinions about many aspects of the case, including some that are not related to the mechanical collision events. However, the engineer is nearly always asked to determine the initial velocities of the vehicles.

As discussed in the attached memo, your team will solve two different accident scenarios and provide a step-by-step approach for accident reconstruction. Upload a draft step-by-step approach to Blackboard using the Assignment tool on Thursday, April 22nd by 8PM. At that time, two new scenarios will be posted. After I provide feedback on your approach, you will then apply your step-by-step approach to solve all of your accident scenarios. Your final turn-in with an analysis of all four accidents, your step-by-step procedure (which can be modified from your Thursday submission), your made up scenario, and your cover memo must be uploaded to Blackboard by midnight on Monday, April 26th.

Effectively Utilizing Industry Members to Assess Student Learning Outcomes in a Senior Project Course

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Abstract

The purpose of this case study was to develop methods to effectively utilize industry members in the assessment of student performance in a senior project course. The primary approach was to create tools that allow industry partners to sponsor, participate, and ultimately assist in assessment of student teams in these courses. The secondary approach was to create and implement surveys that indirectly assess the industry's participation. Both of these methods provided meaningful feedback for the students' performance and ultimately for programmatic student outcomes.

Introduction

The benefit of involving industry members in engineering education has been well documented over the past several decades. Specifically, contemporary academic literature supports the use of industry sponsorship of senior design projects, also known as "capstone" projects (Smith, 2009). Industry sponsorship can take many forms, but most of the time this primarily entails industry members working with and/or reviewing the work of the students (O'Brien et.al., 2003). This provides an outstanding mechanism for students to collaborate with industry members on "real projects". It can also provide a way for students to receive informal feedback on their performance from their industry sponsor (Savage et.al., 2007). Despite these positive results, there remains minimal literature on the use of industry members that actively participate in formal assessment of students.

Description of the Case Study

The Construction Management Program in the Lyles College of Engineering provides students with two separate opportunities to participate in projects. The first is through a senior project course and the second is through the final capstone course in the project. Both of these courses are used to assess students' abiliies to actively participate on project teams. These courses were first reviewed in three primary steps in order to better accommodate active participation of industry members.

The first step to update this course was to identify the currency of the course curriculum. Initial research was performed to identify important issues in the Architectural/Engineering/Construction (AEC) Industry. In addition to the professional experience of the program faculty, an initial literature review showed three primary trends transforming this industry: (1) sustainable design and construction (Beheiry, Chong, and Haas

2006); (2) building information modeling (BIM) (Jones, et al 2009); and (3) integrated project delivery (Johnson and Gunderson 2008). Collectively, these trends are changing the way that industry members operate and the way that many projects are executed.

The second step of this initial research focused on current practices and trends the in delivery of senior project or capstone courses in engineering and construction programs. The literature review provided three primary practices: (1) problem based learning [PBL] (Savage, Chen, and Vanasupa 2007); (2) multidisciplinary approaches; and (3) service learning [SL] opportunities.

The final step was a review of the current CM Program Student Outcomes Assessment Plan (SOAP). The SOAP listed the "student terminal outcomes" for the Senior Project Courses: written and graphic communication, oral communication, interpersonal relationships, leadership and teamwork, independent action, problem recognition and resolution, planning/scheduling/monitoring, skills/tools/techniques, design theory and construction material applications, and computer software utilization.

The review of the SOAP also provided the basis of assessment methods for the CM Program. The Senior Project/Problem courses fall within the second direct measurement method. This direct assessment method is described as "*the level of success the students have as the complete the course of study*." A review of the most recent version of this program assessment provided the following data:

- The Senior Project Courses did not provide current and relevant course content that allowed students to demonstrate STBO's listed in the SOAP.
- The Senior Project Courses did not provide adequate methods to assess each STBO and/or each separate learning objective of the course.

Course Revision Plan

The Construction Management Program then embarked on a multiphase process to revise the curriculum and assessment issues related to the Senior Project Courses. The primary goal of this process was to restructure these (and future) Senior Project courses into sustainability focused, multidisciplinary, service learning capstone courses. The three phases of this revision process were: (1) incorporation of sustainability content and service learning into courses; (2) incorporation of industry member support and participation; and (3) incorporation of multidisciplinary learning approaches.

Phase one of this process began in Fall 2009 and continued through the following academic year (Spring 2011). Sustainability focused projects were added to the Construction Site Planning and Development course (CONST 144) during this first semester. Additionally, the course was updated to align learning objectives with the program SOAP. The program also added a community-based project as a service learning opportunity for student teams during the Spring 2010 term.

Course Revisions and Research

The next phase of the course revision was to implement industry support and to initiate industry involvement in these senior projects. This phase is critical to the transition of Senior Project Courses to true capstone courses. This will also meet the objective "***to prepare students for employment at the professional level in the discipline of construction and its related field.***" This step is critical according to Bernold (2005), stating that "it is evident that the curriculum of an engineering college should be built around an analysis of what a student needs to know to be successful in the workplace."

This phase of the transition was perhaps the most critical to the development of "real life" problem based learning projects. The goal of this phase, to prepare students for employment, utilized an integrated project approach that engaged industry members in these projects. Montoya, Kelting, and Hauck (2008) demonstrate the importance of an industry supported, integrated project approach by stating "employers and [these] graduates agree that graduates … are more productive in their entry level positions when compared to graduates instructed in the traditional model." Additionally, Smith (2009) states "active involvement of an industry sponsor serves to heighten the students interest and brings 'credibility' to the learning objectives and the learning process.

However, there is a significant, and glaring, gap in the academic literature in how to effectively use the services of industry members to assess student performance. Therefore, the focus of this case study (and this phase of the overall project) was to develop, apply, and research the affects of industry members in the assessment of student project based learning in this construction management curriculum.

Methodology

The purpose of this research project was to develop tools to assess student performance in industry sponsored capstone courses. The primary approach was to develop rubrics that will enable industry partners to sponsor, participate, and assist in assessments of student teams in these courses. A secondary approach was to create and implement surveys that indirectly assessed the industry's participation. Both of these methods will provide meaningful feedback for the students' performance and ultimately the program curriculum.

Overall, there were five primary objectives for this project:

1. Align program, industry, and course objectives
2. Align course objectives with terminal outcomes
3. Provide meaningful assessment of student activities
4. Provide effective feedback to faculty members
5. Provide supportive feedback to industry sponsors

The two assessment methods were created in this project:

a) Senior Project "Grading" Rubrics for use by Faculty & Industry Sponsors
    a. Base Rubric for application to all Senior Project Courses

b. Phase Rubric specifically designed for Fall 2010 courses

b) Industry & Student Surveys to ensure continuous improvement of rubrics and the industry members participation

The case study involved several steps. The first step was to perform a literature review in order to determine best practices of incorporating industry participation in the assessment of student projects. As anticipated, these courses leveraged active participation into a formal support program for the Senior Project courses. For instance, CONST 144 has five (5) phases for the senior project. An industry professional, selected for their expertise in their specific area to be assessed, participated in the evaluation of the deliverables for that phase of the project.

The following step aligned the course activities (or project deliverables) with program terminal objectives. The terminal for the Senior Project courses include: (1) Written & Graphic Communication, (2) Oral Communication, (7) Problem Recognition & Resolution, (8) Planning/Scheduling/Monitoring, (9) Skills/Tools/Techniques, (12) Design Theory & Construction Materials, and (13) Computer Utilization.

The next step was to design the rubrics and surveys for the courses. The first part of this process developed a base rubric that could be utilized in all senior project courses. This rubric was also created to align with specific terminal outcomes of the Program. The base rubric established a format that could be easily understood by some one unfamiliar with rubrics and that could be easily modified by the course instructor. The base rubric can be found in Appendix A.

The Senior Project courses require students to create specific professional quality project "deliverables." Therefore, the second part was to use the base rubric format to create prescribed rubrics to grade each project deliverable. Additionally, each rubric was required to assess one of the terminal outcomes associated with the course. This was accomplished by assigning one of the rubric "categories" or "columns" to a specific outcome. As stated previously, the key was to create each rubric in a manner that is easily understood by the industry and faculty member that will be assessing the deliverable. These rubrics were developed in an online survey platform (SurveyGizmo.com) so that the data can be automatically updated. This also further simplified the compilation and evaluation of the data by the use of an iPad to assess students in "real time" during class presentations (see Figure 1 for an example).

The final step was to implement these rubrics in the Fall 2010 Senior Project courses for data collection and evaluation. The results from the rubrics were compiled for presentation to CM Program Faculty during the "Fall 2010 Course Assessment Reports Meeting".

Rubric "Scoring" Methodology

Each rubric was created using a Likert scale for the evaluators "agreement" with the statement. This was chosen for two reasons. First, it is familiar to more evaluators that have ever taken an online survey. Second, it allowed the evaluator to simply state their perception of agreement with the criteria for grading the project and/or presentation category. For example, in Figure 1, question 4 asks if the "Team effectively describes the entire team or firm" for this presentation to the "Owner". (This is the first presentation of the semester for the senior project teams.) The evaluator can then select if they agree or disagree that the student team was able to accomplish this requirement.

The last benefit of using this scoring method is that it is easy to set the "acceptable" range for the project teams. In all cases, the target of "Agree" (or 4 out of 5 points) was the baseline. This then made comparing the scores across teams easier at the completion of the exercise. Additionally, some of the data from the questions could be used in the overall evaluation of program level learning outcomes.

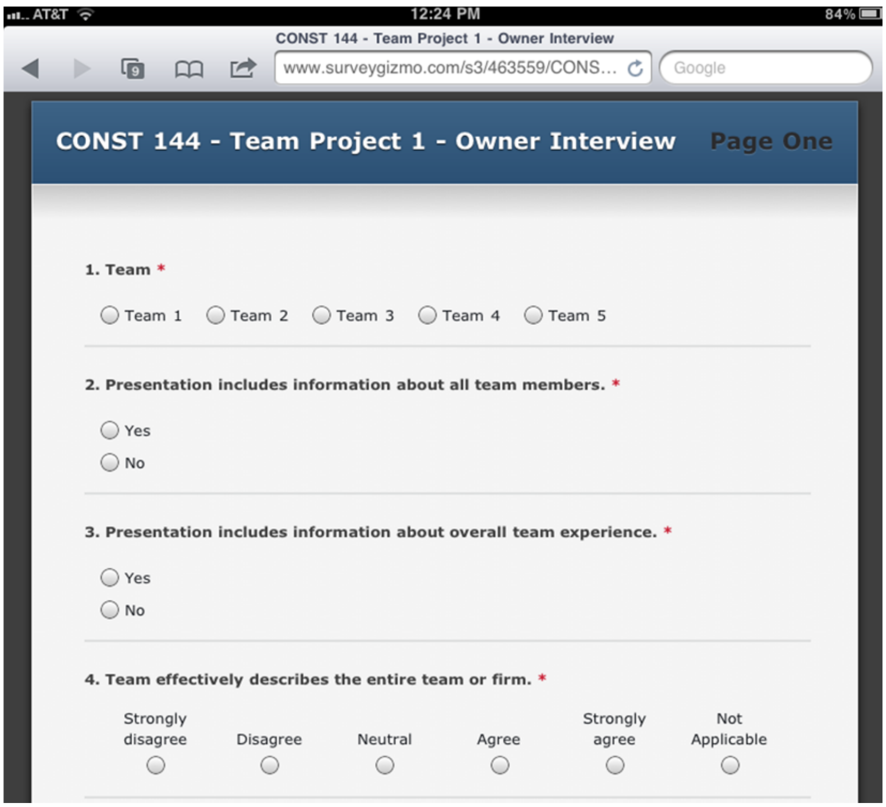

Figure 1. Screen Capture of Project Presentation Deliverable

Results and Recommendations

Assessment Results

The Construction Management Program utilizes course assessment forms to evaluate if students achieved the established course objectives. These forms use both direct (home work, quiz, and exam scores) and indirect (surveys) methods for evaluation purposes. A comparison between the case study course and previous course assessment forms was completed to see if there was any noticeable difference. Here is a brief summary of this comparison:

- There was no meaningful difference in the attainment of course outcomes for this case study compared to previous courses;

- However, students perceived that their learning improved with the additional assessment by industry members;
- Student greatly improved their presentation skills through the semester. As one student said, "this is because we knew industry members would be evaluating our performance."

Case Study Results

As previously stated, and informal survey was formulated to assess the perceptions of industry members and students in this case study. Here is a brief summary of the results from this survey:

- The industry members truly enjoyed participating in the evaluation of students;
- The industry members requested more input on the verbiage used within the rubrics in order to make them more clear;
- The use of an iPad to "score" the student presentations saved a great deal of time when evaluating and grading the assignments;
- Establishment of the base rubric provided a good format for adapting rubrics for specific course deliverables.

Recommendations

Finally, based upon these assessment and the overall efforts during the case study, here are some recommendations for future implementation:

- Engage industry members in the creation of the evaluation criteria. This would improve the rubrics and have the industry member think about how to actually evaluate students.
- Do more research to see if there is an application for using rubrics in education.
- Ensure that students have a copy of the rubrics prior to the assignment. This greatly increases their chances to be successful.

Conclusion

This case study provided a good start in implementing a sustainable method for industry members to participate and assess senior projects. Although there was no statistical improvement in the attainment of learning objectives for the course in this case study, students perceived an improvement. Also, industry members were very interesting in the assessment aspects of the case study. I found that this made them more engaged in the course. Finally, the tools used (an online survey platform and an iPad) were effective, but not optimal. More research needs to be conducted to find tools that are truly productive.

Biographical Information

Mr. Brad Hyatt is an Assistant Professor in the Construction Management Program at California State University, Fresno. His research interests include sustainable design and construction, integrated project delivery, lean construction practices, and construction scheduling

education. Professor Hyatt is also a Registered Professional Engineer and LEED Accredited Professional with over ten years of professional experience in program and project management of facilities, engineering, and construction projects.

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Appendix A. CONST 144 – Base Presentation Rubric

Page One

1.) Team

( ) Team 1

( ) Team 2

( ) Team 3

( ) Team 4

( ) Team 5

( ) Team 6

2.) Presentation includes information about all team members.

( ) Yes

( ) No

3.) Presentation includes all required information.

( ) Yes

( ) No

4.) Assessment criteria #1 (align with terminal outcome).

( ) Strongly disagree

( ) Disagree

( ) Neutral

( ) Agree

( ) Strongly agree

( ) Not Applicable

5.) Assessment criteria #2 (align with course objective).

( ) Strongly disagree

( ) Disagree
( ) Neutral
( ) Agree
( ) Strongly agree
( ) Not Applicable

6.) Assessment criteria #3 (align with course objective).

( ) Strongly disagree
( ) Disagree
( ) Neutral
( ) Agree
( ) Strongly agree
( ) Not Applicable

7.) Assessment criteria #4 (align with assignment objective).

( ) Strongly disagree
( ) Disagree
( ) Neutral
( ) Agree
( ) Strongly agree
( ) Not Applicable

8.) Assessment criteria #5 (align with assignment objective).

( ) Strongly disagree
( ) Disagree
( ) Neutral
( ) Agree
( ) Strongly agree
( ) Not Applicable

9.) Provide additional comments and feedback.

Thank You!

Thank you for taking our survey. Your response is very important to us.

Implementation of Situational Leadership in Engineering Classrooms

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Abstract

The applicability of Situational Leadership in teaching engineering courses has been studied using a quantitative approach. This study incorporates the understanding of the learning process and recognizing the conceptual difference between various communication methods and learning styles, as interpreted in Situational Leadership. Cycling through various styles of leadership facilitates peer-to-peer learning by implementing articulate and practical applications in the course materials to broaden students' perspective toward engineering education and practice.

Introduction

Situational approach to leadership is widely recognized in organizational management. The theory of situational leadership was developed by Hersey and Blanchard (1969) based on leadership style theory by Reddin (1967). This theory has been revised and refined several times to facilitate its implementation in various environments, such as management, supervisory, training, teaching, and so on. The concept of situational leadership in all applications simply consists of matching the leadership style to the development levels of followers. The development levels of followers are measured by their maturity and based on their need for guidance and support. Therefore, the leader selects the best leadership style to focus on combination of task and relationship behaviors. This approach frames leadership style in a two-by-two matrix as shown in Figure 10 [5, 8].

Task or directive behavior, namely guidance, is often perceived as job-related maturity dimension and correlates with the ability or willingness of person to perform. Therefore, the corresponding leadership style to this dimension provides more guidance to focus on high task behaviors. These behaviors typically reflect work structure, organization, schedule, and resource allocation.

Relationship or supportive behavior, on the other hand, is interpreted as psychological aspects of maturity dimension and correlates with the confidence of person to perform. The matching leadership style provides more support for high relationship behavior. This behavior is often characterized by giving considerations to emotional state of the performer and developing mutual respect and trust, as well as improving communication and other soft skills. As a person matures in certain performance, the directive and supportive behaviors advance through four zones of leadership style. This cycle will require the leader to adopt appropriate style for each situation [2, 5, 8].

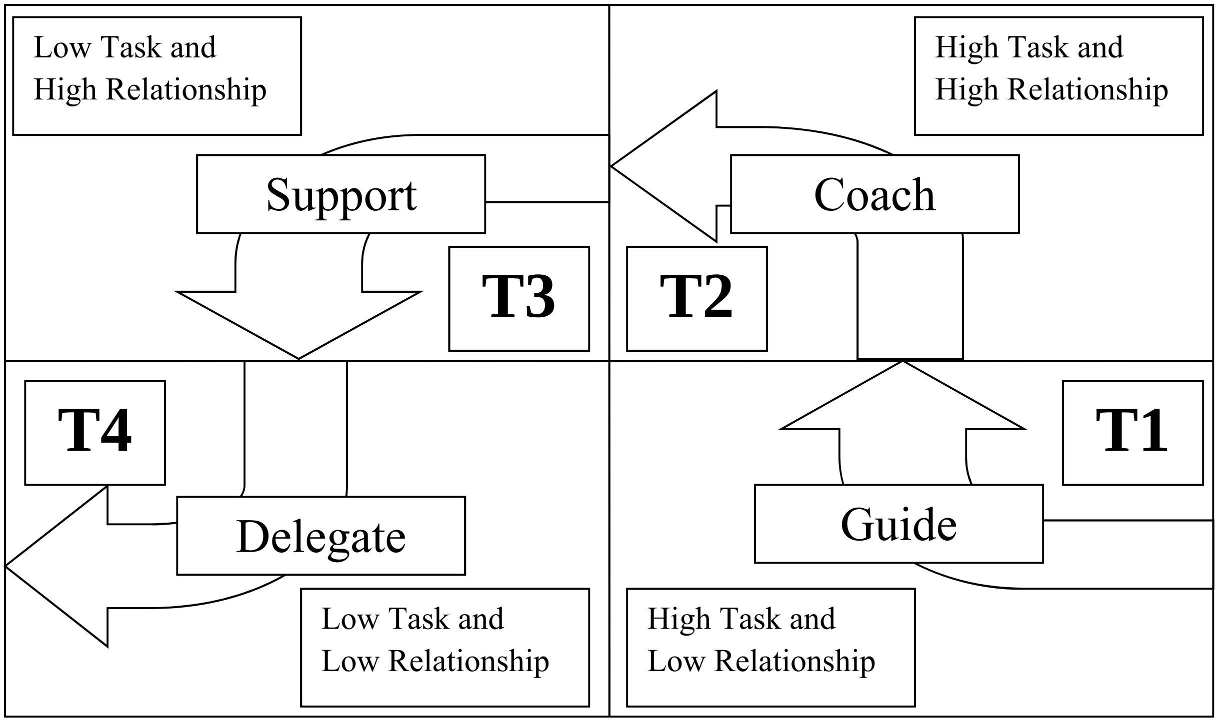

Figure 10 Situational Leadership, after Hersey et al. (1982)

The validity, applicability, and measurability of situational leadership style have been subjects of many researches in various fields, including education [6]. Hersey, Angelini, and Carakushansky (1982) conducted two training courses for small groups of managers, including total of 60 people in four groups, and implemented variations of situational leadership styles. Authors reported that changes in leadership style have a positive impact on the outcomes of training [5]. In a qualitative report, Grow (1991) expanded the idea of implementing situational leadership theory in classroom and discussed how teachers can promote self-learning among learners [4]. In a similar approach, Cramer (1994) emphasized on using assessments as a tool to flex teaching style and engage students in collaborative classroom environment [3]. Meyer (2002) extended such application to clinical training and confirmed applicability of situational leadership in that environment [7]. In a quantitative approach, Vecchio, Bullis, and Brazil (2010) questioned 860 participants about attributes of followers and style of leaders. Authors did not observe any strong correlation between these data and concluded that applicability of the theory might be limited [9].

This brief literature review reveals that typical case studies on implementation of situational leadership theory are qualitative-oriented researches. There are few quantitative studies which have often yielded to contradictory. Further, the implementation of this theory in highly specialized environments, such as higher education classrooms, is challenging. The main purpose of this study is to investigate opportunities and possibilities of a proposed quantitative approach to measure the effectiveness of situational leadership in engineering classrooms.

Situational Teaching

The major tools accessible to an engineering faculty are lectures, presentations, problem solving sessions, and classroom discussions. Further, certain assignments, such as homework, projects, and field studies reinforce the knowledge and skills learned in classroom. Moreover, faculties have an opportunity to measure the outcomes using quizzes and exams. An engineering faculty might even use quizzes and exams as additional learning opportunities.

Classical theories of leadership style and situational leadership suggest that faculties, as leaders of the class, should flex their style based on the readiness of students, as followers. However, managing learning environment in an engineering classroom may not be the same as other leadership fields, such as supervising in workplace or even training in workshops. For instance, each engineering class covers several closely-related topics through an academic term. Faculties guide students to gain interest, motivation, knowledge, and confidence in each topic. The development cycles for various topics are not isolated paths; rather, students move about a spiral motion, in which, finishing each cycle leads to the beginning of a new cycle. Figure 11 represents such learning curve for a typical course.

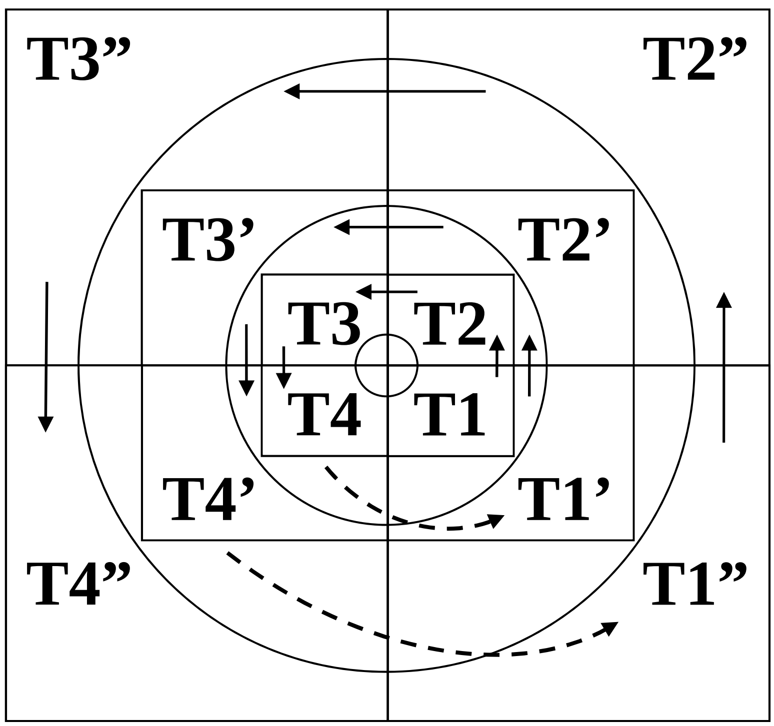

Figure 11 Extended Situational Teaching

As an extension to this model, one may consider combination of closely-related courses to shape an engineering subject area, in which students go through cycles of teaching situation to complete the program. For example, the purpose of an introductory course to structural engineering might be familiarizing students with breath information and gaining their interest to continue the program. Further, more detailed courses on structural engineering enable students to make decisions during the design process. Finally, a senior project advances students to the final stage, where students confidently take over a comprehensive project before graduation. Similarly, but in a broader scale, undergraduate courses often require students to understand and follow certain standards and codes during the design process. So, the information flows from the source of knowledge to followers. In contrast, graduate students are expected to critically analyze those specifications in depth, and even solve problems that might not be adequately addressed by current standards and codes. Thus, followers provide feedback and participate in solving problems without detailed directions. Finally, doctorate students and post-doctorate scholars are generally expected to address new, advanced, and often unique problems, and develop new specifications and guidelines.

T1 style: The situational leadership theory suggests that faculties, as leaders of the class, should emphasize on guiding and directing a person who lacks either the ability or the willingness to perform a task. This style, also called “telling” or “directing”, appears to work best with those who are new to a certain field. At this stage, the main focus is directing rather than supporting. This approach is essentially important in engaging students in the classroom and gaining their interest in the subject. To achieve this goal, one can implement certain techniques, such as discussing case studies, past failures, and future opportunities during the introductory sessions. Further, certain introductory reading assignments will help students to become familiar with the subject. In an engineering program, introductory courses, like introduction to civil engineering, fulfill this objective.

T2 style: As the person matures and becomes interested or motivated, the leadership style should shift toward a more supportive style, also called “coaching” or “selling”. At this stage, the follower is ready to receive information about decision making process, rather than just receiving directions. Further, the leader should persuade the follower to learn more about the technical aspects of the job. The flow of information in the first two stages is often one-way from the leader to the follower. This flow resembles traditional classroom activities, e.g. lecturing and solving examples. The best word to define attribute of a typical student in this stage is knowledge without confidence. Students can learn theories and concept, but, may not be necessarily comfortable to solve practical problems on their own. Homework assignments are common tools to create such confidence. However, students generally do not produce substantial feedbacks about the subject while attempting homework assignments.

T3 style: The third level of development is moving toward participation and sharing ideas under “supporting” leadership. High relationship behavior is the key concept in this stage. The faculty should expect substantial feedbacks from students. This is an opportunity to encourage students to be innovative and creative through class discussions. Asking questions about constructability, sustainability, and ethics will encourage students to participate in learning process beyond traditional frameworks. Carefully-designed quizzes and class projects are typical assignments to reinforce the outcomes of this stage. The importance of relationship behavior requires faculty to employ soft human skills rather than just technical skills to lead students in the second and third stages. The diverse environment in engineering classrooms requires faculties to implement multi-channel communication to engage students with various learning potentials. Further, active listening allows faculties to receive student feedbacks in full spectrum.

T4 style: The fourth stage in situational leadership is called “delegation” to imply the low task and low relationship behavior engaged in this development level. The main purpose of leadership at this stage is allowing followers to take full responsibility for their work with little or zero technical and emotional support by the leader. Exams are often perceived as tools to measure the rate of students' success in carrying such responsibilities. In addition, faculties may need to implement alternative measures to gage such success rate throughout the academic term as well as at the end of the class. Term projects are other measures to assure that students are capable and confident enough to perform engineering tasks by themselves.

While implementing appropriate leadership style enhances learning experience, employing inappropriate techniques and tools might create a mismatch between teaching style and development level of students. Obviously, the wide range of maturity level among students is a challenge in implementing one single style at a time. Therefore, implementing each leadership style might be accompanied by employing near match tools. For instance, lecturers may combine lecture sessions with problem solving sessions, or incorporate case studies in term projects. Further, it should be noted that situational leadership does not necessarily require faculties to adapt to the current maturity level of students. Rather, faculties should utilize a progressive style to pull students out of their comfort zone and improve their development level. In this respect, for instance, coaching students (T2) is not intended to just connect to students at high task and high relationship behavior. The main purpose of implementing this style is encouraging students to move out of low relationship behavior (T1), namely telling stage, and prepare them to move to low task behavior (T3), which is participating stage. Employing a wide range of tools, including presentations, solving examples, and homework assignments, will help students at various stages to follow the lead and feel confident in the new reception level. Table 2 shows the match and mismatch zones in teaching style.

Table 2 Interactions of Teaching Styles, after Grow (1991)

Style	Match	Close Match	Mismatch
T1	T1	T2 (and T4 from previous cycle)	T3 (and T4 from current cycle)
T2	T2	T1 and T3	T4
T3	T3	T2 and T4	T1
T4	T4	T3 and (T1 from next cycle)	T2 (and T1 from current cycle)

Methodology

A group of 74 undergraduate engineering students from three classes were questioned in this study. The questionnaire consisted of two main sections on lecture components and class assignments (Table 3). Questions asked students to identify the most and the least helpful part of each component or assignment in respect to given outcomes. Total of 21 outcomes were included in the questionnaire as listed in Table 4. For instance, a sample question asked students to identify the most and the least helpful class activities for sharing ideas. Additional sections were dedicated to general academic information, for statistical purposes, and general comments, to encourage participation in the study.

Table 3 Sample class components

Lecture Components	Assignments
Theory and Concepts, Problem Solving, Class Discussions, Practical Implementations, and Others	Required Readings, Homework Assignments, Quizzes, Exams, Class Projects, and Others

Table 4 Sample outcomes

Gain interest
Provide specific information
Direct and guide
Gain knowledge
Explain decision making process
Persuade learning
Gain confidence
Encourage performing
Share ideas
Perform independently
Take responsibility

Results

Table 5 presents partial results from the section on general academic information. These results show that most participants are either junior or senior students in undergraduate program. Students at this academic level have often been exposed to engineering courses, and perhaps, their continued presence in engineering classes shows their interest in this field of study. Further, participants had nearly the same GPA, prerequisites grade, and expected grade in current course of 3.2 out of 4. This consistency suggests that studied classes are not substantially different from their previous classes in terms of difficulty. Moreover, most students stated that the current course is part of their major program.

Table 5 General academic information

	Sophomore	Junior	Senior	Graduate
Year in School	5%	15%	77%	3%
	Major Core	Major Elective	Minor	None
Requirement this course fulfills	57%	40%	1%	1%
Fresno State GPA	3.18 ± 0.79			
Average grade for prerequisites	3.16 ± 0.98			
Expected grade in this course	3.20 ± 0.67			

Table 6 shows the second part of general academic information, in which students state their preparedness for the current course. As indicated, students claimed to be fairly prepared for the course in terms of ability and interest. The outcome confirms that students are perhaps within the second stage of teaching style, T2, which is high task and high relationship behavior.

Table 6 Preparedness of students

	Very low	Low	Average	High	Very High
Background in prerequisites of the course	3%	14%	14%	9%	10%
Subject interest before taking the course	1%	7%	18%	19%	5%

Nearly 50% of students stated that Homework assignments were the most helpful assignment to achieve most outcomes as listed in Table 4. These assignments were designed to coach students throughout the second stage of teaching style, T2. Therefore, it is not unexpected to observe that surveyed students recognize this component as the main learning tool. This simply shows that homework assignments are a match for students with high task and high relationship behavior. Further, nearly 40% of students found the exams to be the least helpful components in those learning process components. Obviously, exams were designed to measure performance of students in the last stage of teaching style cycle, low task and low relationship behavior. As previously stated, this style is a mismatch for coaching style. This claim can be further reinforced by noting that students marked exams as the most helpful component in taking responsibility for their performance. Taking responsibility reflects the requirement of T4 style. Further, the reading assignments are selected as the least helpful component for this purpose. Reading assignments in studied courses correlate to the T1 style and expected to be a mismatch for T4.

Table 7 Typical number of responses for the most helpful assignments

	Required Readings	Homework	Quizzes	Exams	Class Projects	Other
Explain decision making process	20	36	2	0	5	3
Persuade learning	12	30	5	7	3	3
Gain interest	14	19	3	3	15	8
Gain knowledge	12	42	0	1	4	2
Gain confidence	3	45	4	3	5	2
Take responsibility	4	20	5	26	6	0

Table 8 Typical number of responses for the least helpful assignment

	Required Readings	Homework	Quizzes	Exams	Class Projects	Other
Explain decision making process	18	4	14	25	3	3
Persuade learning	18	6	10	19	6	3
Gain interest	11	3	10	32	4	2
Gain knowledge	11	2	25	25	2	1
Gain confidence	10	2	18	33	2	1
Take responsibility	31	5	6	13	3	5

Students also selected the most and the least helpful lecture components. Generally, more than 40% of students chose problem solving sessions as the most helpful tool. This confirms their response in acknowledging homework to be the most helpful assignment, and reinforce their high perception of T2 style. However, few responses did not follow this trend. Nearly 73% of students believe that class discussions were the most helpful part of the class to share ideas. This is considered as the key element to progress toward participating style, T3. Further, nearly 80% of students were equally divided on the section that persuaded them to learn. The top scores were recorded for problem solving, class discussions, and practical implementation. This is an interesting response in recognizing the importance of multi-channel communication. Students with various development skills simply respond to different teaching style, ranging from T2 to

T4. Finally, more than 40% of students stated that class discussions on practical implementation helped them to gain interest in the subject. The classical situational leadership theory tends to classify gaining interest in T1 and practical implementation in T4, which is expected to represent a mismatch. However, in the extended form of situational leadership, T4 is also a predecessor for T1 in the next topic of the class. For instance, while students learn about the practical implementation of certain engineering problems and its potential issues, they might be introduced to the need for new solutions and become interested in the next topic.

Table 9 Typical number of responses for the most helpful lecture components

	Theory and concepts	Problem solving	Class Discussions	Practical implementations	Other
Explain decision making process	13	30	12	10	2
Persuade learning	9	18	17	18	4
Share ideas	2	8	48	6	1
Gain interest	5	13	17	30	2
Gain knowledge	12	36	7	9	2
Gain confidence	3	37	13	11	3
Take responsibility	2	34	11	15	3

Conclusions

The studied methodology employs communication skills to enhance student's participation by developing a teaching style based on multi-channel communication and active listening. This optimized student-oriented environment requires adopting different styles based on readiness of students and their current stage of learning. The flexibility in teaching style allows the instructor to apply different techniques to guide and persuade students in early stages of learning, and to keep them engaged through active participation and communication, while mastering their knowledge and skills. Further, adopting appropriate style at each stage based on the needs of each individual student keeps the communication open between students and the instructor, and makes the instructor approachable for students.

The foregoing guidelines can be adopted in preparation of course materials and evaluation methods. Whereas, the objective in developing early homework and similar assignments is coaching students to learn fundamental theories and technical skills; the term projects and other comprehensive assignments are developed to raise students' confidence in applying their knowledge. These assignments, or other special assignments, such as bonus or extra credit projects, could also improve students' writing skills. Moreover, implementing human skills and utilizing various aspects of emotional intelligence promote their teamwork, presentation, and other soft skills through special assignments, such as term projects and seminars. On the same line, quizzes and exams are designed to enhance students' abilities to use engineering judgment for solving new problems under pressure.

Accomplishing these objectives prevents black box education, and enables future engineers to recognize the key concepts and challenges of engineering problems and to rely on firm theoretical backgrounds in solving problems. This methodology motivates students to take more responsibility in their learning process, and encourages them to act as independent problem solvers. The essential outcome of this process is to promote their engineering judgment skills as the key quality for professional engineers.

Future Research

Performed study was limited in the scope as well as the number of participants. The consistency of students in respect to their development levels facilitated the comparative analysis of results. However, future research should include students at different levels, such as junior or graduate students, to examine implementation of situational leadership in these levels. Further, enhancement of probabilistic reliability of results requires a substantial increase in the number of participants. Moreover, the accuracy of responses to direct questions needs to be verified using alternative approaches, such as indirect tests and evaluations.

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Effectiveness of Using Visualization in Construction Education

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Abstract

The need to integrate advanced education technology tools, such as interactive simulations and visualizations, into the curriculum has been recognized by accrediting bodies because these tools enhance student learning and improve the quality of an engineering education. In this paper, the authors describe a visualization-based teaching approach to construction education in which different visualization tools, including video clips, 3D models, drawings, and pictures/photos, together with complementary texts, are used to assist students in deeper understanding and effective mastering of materials. The proposed teaching method was used to teach a construction management course offered at California State University, Long Beach. An assessment rubric was developed to evaluate the effectiveness of the proposed teaching method and the evaluation results indicated that, overall, the visualization-based teaching approach helped students to effectively learn the materials. With continuous modification and improvement of the course materials and interactive functions, the proposed visualization-based teaching tool is expected to help students deeply understand and effectively master the subject materials.

Keywords

Learning Effectiveness, Learning Assessment, Visualization, Engineering Education, Learning Performance, Teaching Performance.

Introduction

Previous education-related research works have revealed that advanced technology tools such as interactive simulations and visualizations enhance student learning and improve quality of engineering education.[1, 2, 3, 5, 11] For example, interactive multimedia units provide motivation, increase learning rate, contribute to retention, and even help effectively manage large classes while supporting the teacher as facilitator. [1, 4, 9, 13] Visual simulations are particularly effective at deepening understanding of abstract and highly mathematical subjects such as electromagnetism.[8] Likewise, three-dimensional animation and walkthrough computer models demonstrate construction processes and complementary texts describe the various steps for dual coding of information.[7] In construction management curriculums, students learning about construction processes usually need additional tutorials with illustrative animations, simulations, or further explanations with visualizations. For instance, when learning construction technology, students need to visualize materials and sequences of construction process, i.e., how all components of a facility are assembled. This paper presents the development and implementation of a "learning with visualizations" method which is designed to assist students in more fully understanding and effectively mastering the materials. The proposed visualization-based learning method was used to teach a construction engineering management course at California State University, Long Beach. An evaluation of the effectiveness of the teaching method was conducted using an assessment rubric and the results of the evaluation are discussed.

Visualization-Based Learning Framework

In the proposed visualization-based learning framework, the content of the materials to be covered was organized in three main modules: Learn, Practice, and Assess. These three separate modules enable students to achieve a deeper understanding as they undergo a three-stage learning process:

(i) Learning: Students go through the dialogues and visualizations to enhance their knowledge and understanding. The lecture notes are prepared and organized in chapters, sections, and subsections including texts, dialogues, and illustrative visualizations (e.g. video clips, drawings, 3D models, images, and photos).

(ii) Practicing: At the end of each chapter, questions as "food for thought" are given as multiple-choice quizzes or tests, which are scored to assess the student's knowledge. Students are asked to solve practical problems using their acquired knowledge and apply what was learned to unfamiliar problems.

(iii) Assessing: Students' learning is assessed by means of questions as "food for thought." Their answers to these questions are scored and the scores are used to assess what they've learned against objectives of the course. For each chapter, based on the assessment outcomes (i.e. the student scores), the instructor provides students with recommendations for what topics in the chapter need to be reviewed before going further in subsequent chapters to be covered in the following lectures.

To make the three learning modules interactive, the proposed visualization-based learning framework was implemented in Macromedia Studio 8™ and used a computer teaching tool named VisualLearning. Macromedia Studio 8™ was selected for this implementation since it offers the broadest range of creative tools to create interactive dialogues and visualizations using advanced graphics, text, animation, video and audio tools.

Implementation

The proposed teaching tool, VisuaLearning, was used to teach a construction engineering management course, CEM 121 Construction Drawings, offered at the Department of Civil Engineering and Construction Engineering Management at California State University, Long Beach. Figure 1 shows a typical screen shot of VisuaLearning, in which texts, 3D images, video clips, and drawings are entered as illustrative visualizations for the foundations of a residential construction project to be covered in the course CEM 121. After going over the learning materials for a particular subject (e.g. Graphic Vocabulary), students are prompted to answer questions in a quiz or test about what has been learned. These quizzes and tests are scored to make sure students understand the materials before going further in the subsequent chapters.

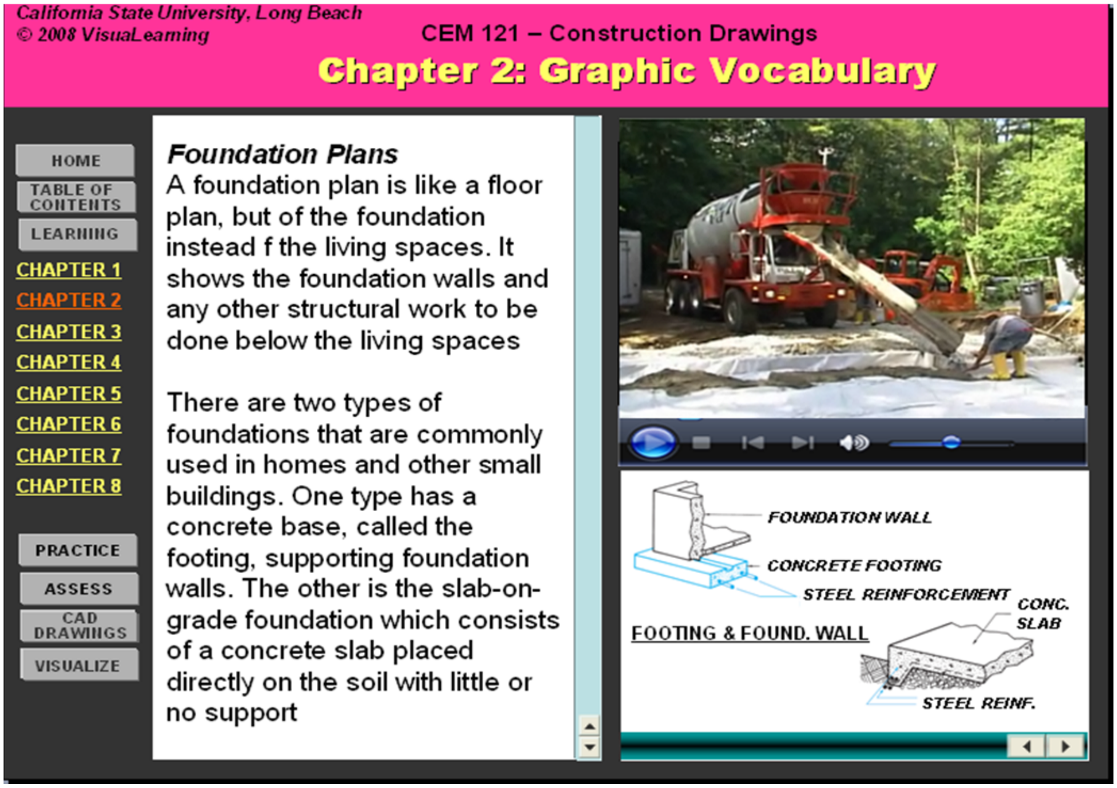


Figure 1. A Typical Lecture Note: Concrete Foundations

Assessment of Effectiveness

The effectiveness of proposed teaching methods was evaluated by means of different assessment tools. In addition to the traditional assessment tools such as homework, quizzes, tests, exams, lab reports, oral presentations, and projects, a rubric assessment tool was developed. This tool is used to evaluate the overall student achievements with respect to the learning objectives of the course. Once the course of study has been established, the overall expectations are determined through reviewing course-learned objectives, lecture notes, handouts, and materials collected on assessment strategies. To ensure that the overall expectations are being met, the performance criteria and evaluation methods should be established for assessment. Table 1 shows the performance criteria and evaluation methods for the course CEM 121, where the proposed visualization-based teaching method was implemented.

Table 1. Performance Criteria and Evaluation Methods.

Outcome 1: Understand the language of construction drawings.
The student will be able to identify lines, symbols, and standards commonly used in construction drawings.
The student will be able to accurately interpret information.(e.g. dimensions, symbols, graphs, texts, etc.) in construction drawings for both residential and commercial construction.
The student will be able to interpret and relate written specifications of a construction project to drawing plans of that project.
tion methods: examinations, assignments and in-class exercises)
ne 2: Understand and read the different construction drawings in a set of plans for a building
The student will be able to identify, define, and relate the different construction drawings.
The student will be able to read site plans, foundation plan, floor plans, elevations, sections, details, door and window schedules in an architectural prints.
tion methods: examinations, assignments, and in-class work)
Outcome 3: Conduct quantity takeoff practices for construction drawings
The student will be able to compute mathematical values (e.g. material quantity, measurements) as part of interpreting construction drawings using the architect's and civil engineer's scales.
tion methods: examinations, assignments and in-class exercises)
Outcome 4: Apply visualization skills to understand the construction drawings
The student will be able to use 2D and 3D visualization skills to sketch and draw construction details using pictorial drawing or orthographical projection.
The student will able to use CAD applications including 2D and 3D modeling software (e.g. AutoCAD, Revit Architecture, ArchiCAD) to create basic construction details.
tion methods: examinations, assignments and in-class exercises)

A rubric is a powerful and useful scoring tool for both teaching and assessment[6]. The performance criteria listed above are used to develop the rubric assessment tool and Table 2 presents the elements of the assessment tool. The assessment rubric consists of two performance metrics, which include (1) ability to develop appropriate levels of detail for construction projects and (2) ability to develop appropriate levels of quantity-take off for construction projects. Student performance on each metric has four possible levels and is assessed on a scale of 1 to 4 with novice performance having a score of 1, apprentice performance having a score of 2, proficient performance having a score of 3, and exemplary performance having a score of 4.

Table 2. Assessment Rubric for Performance Criteria

Performance Criteria	Score (1-4)	Novice (1)	Apprentice (2)	Proficient (3)	Exemplary (4)
Ability to develop appropriate levels of **detail for construction** projects		Rarely use the proper method to develop construction details for construction projects	Use the proper method , some of the time, to develop construction details for construction projects	Use the proper method , most of the time, to develop construction details for construction projects	Always use the proper method to develop construction details for construction projects
Ability to develop appropriate levels of **quantity-take off** for construction projects		Rarely use the proper method to develop quantity-take off for construction projects	Use the proper method , some of the time, to develop quantity take off for construction projects	Use the proper method , most of the time, to develop quantity take off for construction projects	Always use the proper method to develop quantity take off for construction projects

Assessment Results and Discussions

This section describes assessment results based on student works and said assessment is made using the assessment rubric developed in this paper. The assessment results consist of two factors: (1) overall student achievement which evaluates the effectiveness of the learning objectives and (2) the potential for continuous utilization of the proposed visualization-based teaching tool by showing no significant difference in student performance for two consecutive years, 2009 and 2010. In order to analyze the assessment results, we collected and evaluated students' works using the assessment rubrics tabulated in Table 2. The CEM 121 Construction Drawings course, where this outcome is covered and achieved, is analyzed using the rubric for this outcome. We graded the students' works not only for the purpose of grading against answer keys but also to assess the achievement of course outcomes. The rubric was used to collect direct assessment data of 23 and 24 students for Fall 2009 and Fall 2010 respectively. Table 3 shows descriptive statistics by performance criteria. Figure 2 shows the difference in performance criteria between the two student groups with regard to construction details and quantity takeoff.

Table 3. Descriptive Statistics by Performance Criteria

Class Group	Fall 2009		Fall 2010	
Performance Criteria	Construction Details	Quantity Takeoff	Construction Details	Quantity Takeoff
No. of Students	23	23	24	24
Student average score achieved	36.43	41.00	34.77	39.00
Perfect score	41.00	54.00	41.00	54.00
Percentage (%)	88.87	75.93	84.81	72.22

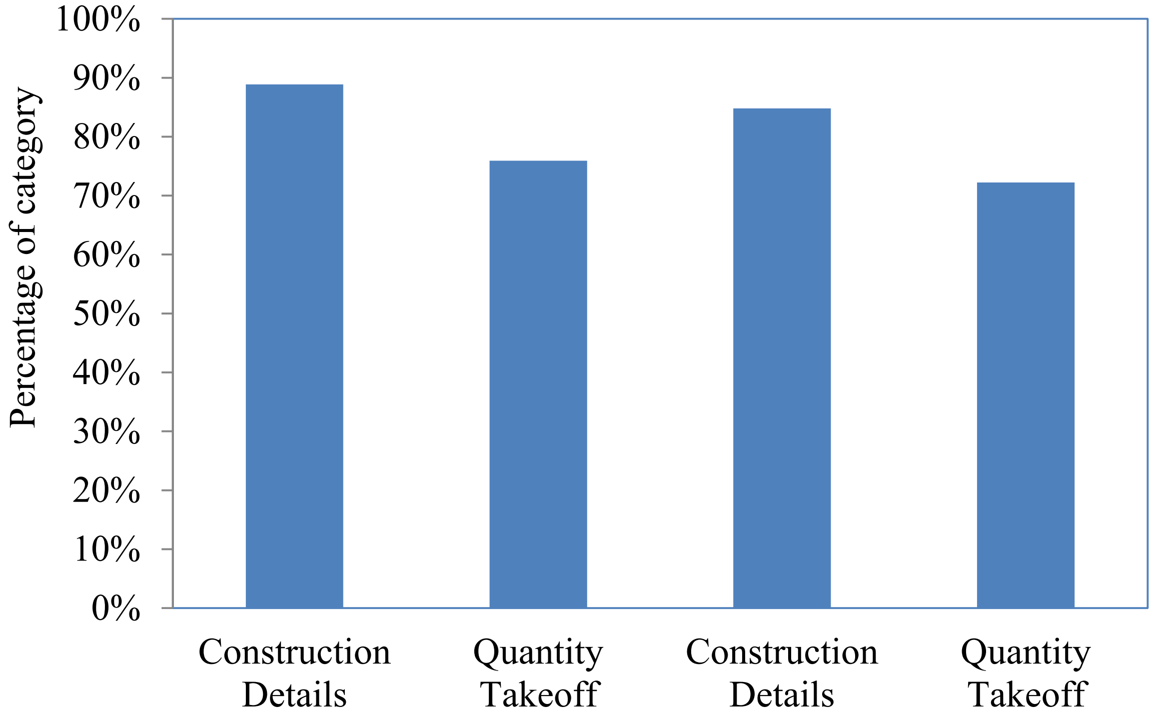
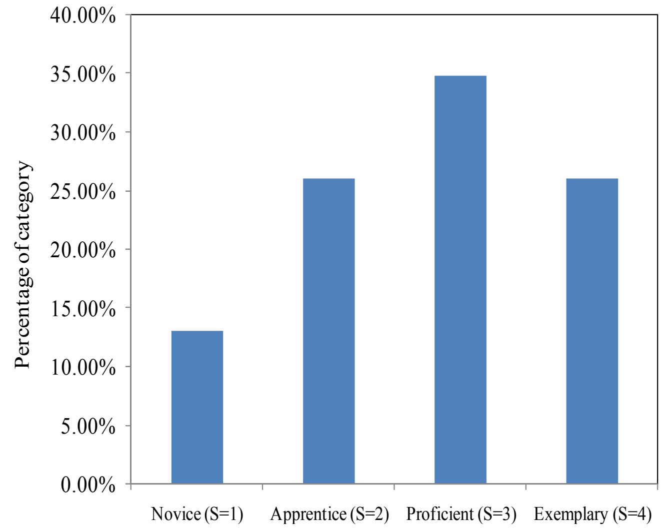


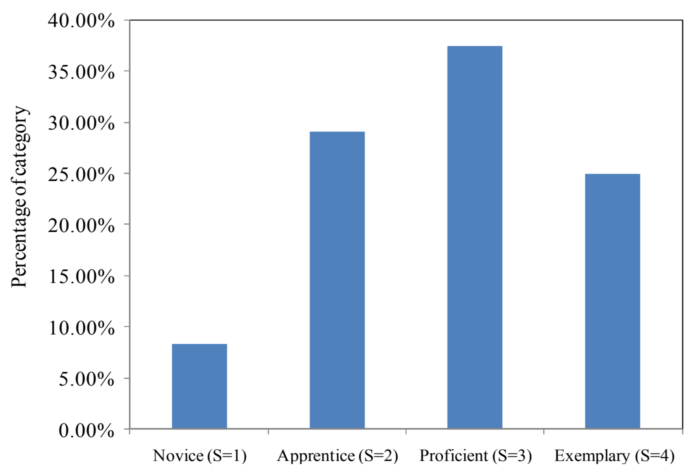
Figure 2. Comparison of performance criteria between the two student groups

The percentages shown in Table 3 was obtained for each semester and each metric by dividing the student average score achieved by the maximum score that students can obtain. It should be noted that the outcome of each performance criteria is achieved at a level that is greater than the acceptable level of 70.00%. A percentage greater than or equal to 70.00% in Table 3 implies that students demonstrated the achievement of outcome. The percentages for the assessment of construction details performance are 88.87% and 84.81% for Fall 2009 and Fall 2010, respectively, while those of quantity takeoff performance are 75.93% and 72.22%, respectively. The results indicate that students demonstrate competency at a proficient level. The effectiveness of using visualization was shown for both construction details and quantity takeoff.

An experiment was conducted to show the potential of the proposed teaching tool using visualization for continuous utilization in the CEM 121 course. In most cases, we do not know the actual variance or standard deviation of either of the two student groups, Fall 2009 and Fall 2010. The student samples are randomly and independently drawn from respective students that the samples are normally distributed and that the population variances are equal. Thus, the experiment method using a pooled-variance t-test is appropriate because it determines whether or not there is a statistically significant difference between the means of the two populations.[10, 12] Figures 3(a) and 3(b) show the distributions of overall student performance based on the rubrics for Fall 2009 and Fall 2010 respectively.



(a) Fall 2009



(b) Fall 2010

Figure 3. Comparison of Overall Assessment Results: (a) Fall 2009 and (b) Fall 2010

The experiment aims to compare the overall student performance between two groups for the proposed visualization-based teaching tool. The research hypothesis is to show that there is no significant difference in student performance for two consecutive years, 2009 and 2010, so that the teaching tool has a potential to continuously promote students' understanding and interest in construction. A T-test for the difference between the means of two independent student groups, Fall 2009 and Fall 2010, was conducted using Minitab 16®. The hypotheses to test whether the overall student performance ($\mu 1$) obtained from the class of Fall 2009 exceed those ($\mu 2$) obtained from the class of Fall 2010 are Ho: $\mu 1 - \mu 2 = 0$ and Ha: $\mu 1 - \mu 2 > 0$. Table 4 tabulates the statistical results for overall student performance.

Table 4. Statistical Analysis for Overall Student Performance

Class Group	Fall 2009	Fall 2010
No. of students	23	24
Mean	2.74	2.79
Standard Deviation	1.01	0.93
t-score (p-value)	-0.19 (0.573)	

At a 0.05 level of significance, the null hypothesis is not rejected because the p-value is not less than 0.05. We have sufficient evidence to show that the null hypothesis is true. From this we conclude that the interactive visualization-based teaching tool proposed here can be utilized as an effective teaching tool for any group of students that takes the CEM 121 Construction Drawing I course offered at the Department of Civil Engineering and Construction Engineering Management at California State University, Long Beach. With the continuous modification and improvement of the course materials and interactive functions, the proposed visualization tool is expected to help students achieve a deeper understanding, apply learning to unfamiliar problems, and optimize achievement of predefined learning outcomes through a diagnostic feedback loop.

Conclusion

The integration of interactive visualizations in teaching helps students deeply understand abstract subjects in construction courses. In an attempt to improve the quality of construction education, a visualization-based teaching tool was developed and implemented at the Department of Civil Engineering and Construction Engineering Management at California State University, Long Beach. In the proposed teaching tool, the student is provided with visual learning objects including graphics, animation, video, three-dimensional models, and illustrative images/photos, which are used as primary learning features. These learning objects consist of modules that help students achieve a deeper understanding (learn), apply learning to unfamiliar problems (practice), and optimize achievement of predefined learning outcomes through a diagnostic feedback loop (assess). The tool was used to teach a construction engineering management course and evaluated for its effectiveness. In addition to the traditional assessment mechanisms such as homework, exams, labs, etc., a rubric assessment tool was developed and used to evaluate the learning performance of students. The evaluation results indicated that, overall, the visualization-based teaching approach helped students to effectively learn materials. It was found that the visualizations provide dynamic representations of knowledge and increase classroom interaction and students' personalized learning experience. Overall, the visualization-based teaching method promotes students' understanding and interest in construction, which can lead to higher student retention rate.

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Service Learning Project in a Renewable Energy Engineering Course

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One of the most significant challenges facing this coming generation of engineers is how to fight the complex issue of climate change. One aspect of this that is having an increasingly important role is alternative and renewable energy technologies. Emerging applications such as solar cells, wind energy conversion devices, and fuel cells involve significant contributions across a range of traditional engineering disciplines.

San José State University offers a general engineering course on Renewable Energy Engineering. The course is open to juniors, seniors, and graduate students of all engineering majors and is part of the College of Engineering's minor in Green Engineering. The course has been offered three times, to date, and typically has students from every engineering major on campus. The class covers a range of renewable energy topics including: how traditional energy is produced, measured, and sold; solar thermal; photovoltaics; wind; hydropower; fuel cells; biofuels; geothermal; and ocean, wave, and tidal energy. In all of the topics, the class covers enough of the engineering fundamentals to allow for mini-design projects in each technology. The classroom periods use an active learning methodology. The classes are structured such that the students work together in multi-disciplinary teams where each student is able to bring the expertise of their major to understanding the technology. For example, the background of mechanical engineers combined with electrical engineers will allow a team to begin to grasp the basic fundamentals of fluid flow and power generation needed to understand how a hydropower plant operates.

A significant assignment in the class is a community-based service learning project done in multi-disciplinary teams. Each team is assigned a renewable energy technology (such as wind power) at the start of the semester. They have a series of assignments designed to give them technical depth in the area and confidence as an "expert" in the technology. Then, the teams design a hands-on teaching demonstration for their technology. They bring this to an after-school program for 4^{th}- 7^{th} graders at a nearby community center. The community center is part of a unique university/ city/ community partnership (CommUniverCity). The service learning project is facilitated by San José State University's Center for Community Learning and Leadership. Assessment of the service learning shows that the project increases students' self reported understanding of the engineering fundamentals, as well as increases their confidence and motivation to make a difference in society.

Need for Renewable Energy Engineering

The burning of fossil fuels and the rapid deforestation of the globe have created an increase in CO_2 gases in the atmosphere and a heating up of the earth's temperature.[1] Data shows an exponential change in CO_2 in the atmosphere in the last several decades.[1] This has been correlated with a warming of the earth's surface temperature.[3] Coupled with the problem of climate change, nations are also struggling with a growing demand for energy alongside a shrinking pool of easily accessible fossil fuel.[4] These challenges are spurring an interest in alternative, renewable energy sources.

Alternative, renewable energy sources include solar thermal; photovoltaics; wind; hydropower; fuel cells; biofuels; geothermal; and ocean, wave, and tidal energy. The alternative energy industry is predicted to grow dramatically in the next two decades, with increasing career opportunities for most engineering majors.[5] These renewable energy technologies depend on an understanding of a broad range of engineering disciplines. Research, development, and manufacturing of these renewable energy devices will require multi-disciplinary teams of engineers.[6]

San José State University's Renewable Energy Engineering Course

To be successful in the industry, engineers must have a strong foundation in their engineering discipline, a broad understanding of the complexities facing renewable energy, and an ability to work effectively on multi-disciplinary teams. With these goals in mind, the Davidson College of Engineering at San José State University has developed a minor in green engineering.[7] The minor was established in Fall 2008 and is open to all engineering majors. One of the required classes in the major is Engr 102: Renewable Energy Engineering. The class is taught in the General Engineering department and is open to all engineering majors. The class has been offered three times, starting in Fall 2008. All of the engineering majors have been represented. Figure 1 shows the percentage of engineering majors from the 59 students enrolled in the class from Fall 2008- Fall 2010. While it is an undergraduate course, it is also open to graduate students as an elective. Students must be at least a junior to take the course, guaranteeing that all students have a foundation in science and engineering fundamentals. The class is 70% undergraduate and 30% Master's students.

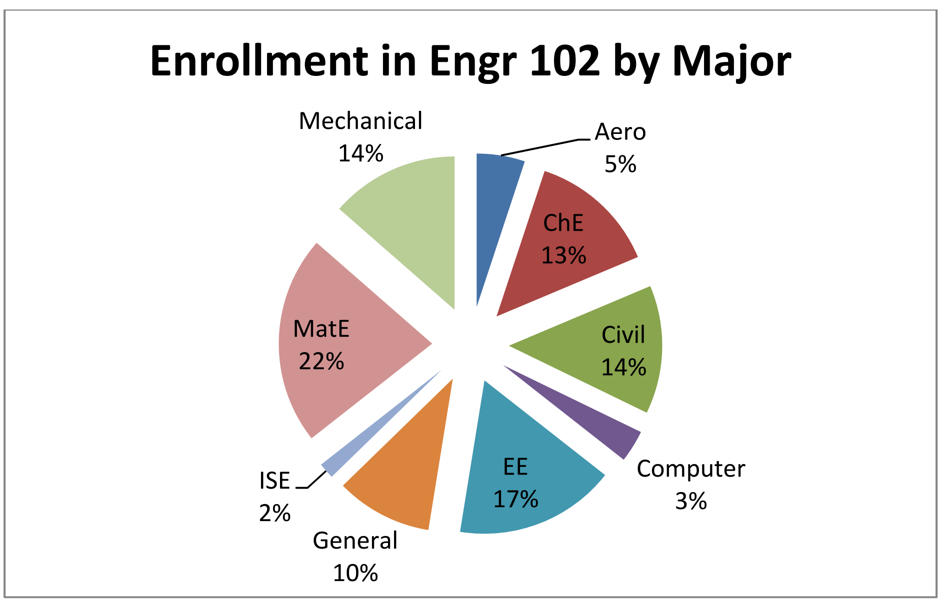

Figure 1: Majors of 59 San José State University students enrolled in Engr 102 from Fall 2008 to Fall 2010.

The Renewable Energy Engineering course covers a range of renewable energy topics including: how traditional energy is produced, measured, and sold; solar thermal; photovoltaics; wind; hydropower; fuel cells; biofuels; geothermal; and ocean, wave, and tidal energy. The class includes a number of guest speakers and tours that are designed to give students an overview of career opportunities in renewable energy. The 15 week curriculum is shown in Table 1. In each topic, students learn the "big picture" context of each technology including the advantages and disadvantages from societal, environmental, economic, and engineering perspectives. The basic engineering fundamentals are also covered, and students perform an open ended design exercise to optimize the performance of each technology.

Table 1: Topics covered in San José State University's Renewable Energy Engineering course.

Week	Topic
1	Introduction to Renewable Energy
2	Energy Consumption & Sources **Tour of SJSU power plant**
3	Measuring Solar Radiation
4	Solar Thermal **Tour of solar thermal lab**
5	Photovoltaics **Hands on photovoltaic lab**
6	Photovoltaics **Photovoltaic industry guest speaker**
7	Fuel Cell **Fuel cell industry guest speaker**
8	Hydropower **Three Gorges Dam video**
9	Wind Power **High altitude wind guest speaker**
10	Wind Power **Wind turbine guest speaker**
11	Biofuels **Biofuels industry guest speaker**
12	Wave Energy
13	Tidal & Ocean Energy
14	Ocean Thermal Energy Conversion
15	Geothermal **Community Center Project**

The classroom sessions are run in an active learning style; there is no lecturing. Depending on the topic being covered, some engineering majors will have had more of a relevant background of the fundamentals. For each topic, students are divided into multi-disciplinary teams where an emphasis is made to ensure student background on each team is diverse and that each team has members who have the needed functional pre-requisites for comprehending the material. For example, the background of mechanical engineers combined with electrical engineers will allow a team to begin to grasp the basic fundamentals of fluid flow and power generation needed to understand how a hydropower plant operates.

The active learning pedagogy has been shown to increase student engagement and significantly improve learning.[8] For an overview course such as this, traditional lecturing could become a situation where the faculty member lists statistics and engineering fundamentals related to the technology, keeping the information transfer at the low levels of Bloom's taxonomy. The active learning methodology is used to engage the student in the synthesis and analysis levels of Bloom's taxonomy from the initial introduction of a topic.[9] Each class period is structured to engage the students in thinking and reasoning throughout the class period.

Students need to come to class prepared, having read the assigned background material.[10] They then are asked to brainstorm in their teams on the main structure of the technology (main engineering components and the advantages and disadvantages of the technology). The purpose of these initial questions is to place the new material within the context of their current understanding, thus increasing retention.[11] This component of the class challenges the students to think about the technology in a broader perspective, including environmental, societal, and economic constraints as well as engineering challenges.

Following that, students are guided through reviewing and applying the key equations and concepts needed to utilize the technology. The equations and concepts were already covered in the assigned reading. Emphasis is placed on understanding what the real world factors are in the math and how these factors would influence the performance of the technology. The goal of this level of questioning is that students are able to apply the equations and engineering fundamentals to real situations. In placing the material within the context of the technology, students should be engaging in a higher level of learning.[12] In the final stage of the active learning exercise, student teams apply what they have learned to a small, open ended design calculation related to the technology. Table 2 shows the levels of questioning students are guided through in each topic of the course.

Table 2: Schematic of the sections in the active, team based, in class exercise for each renewable energy topic.

Individual Class Preparation: Read assigned textbook chapter before class
Phase 1: **Synthesis** of prior knowledge and **contextualization** of the "big" picture including the environmental, societal, economic, and engineering advantages and disadvantages of the technology
Phase 2: **Application** of calculations and engineering fundamentals to real world examples
Phase 3: Open ended **design** calculation to optimize performance

Throughout the active learning exercise, the faculty member interacts with each group, answering questions and facilitating team interaction. The teams are interrupted intermittently throughout the class period to review the answers, either by having several teams orally report their answers or write them on the board. The solutions to the active learning exercise are always posted on the class site following the class period.

In all of the topics, the classes cover enough of the engineering fundamentals to do mini-design projects in each technology. These are done individually as homework exercises. The design problems reinforce the calculations and engineering fundamentals covered in the class and encourage the students to utilize outside resources such as media articles related to the different technologies. There is an emphasis on building an understanding of the engineering constraints that limit the performance of the technology.

Community Based Service Learning Project

A key learning activity in this class is a community-based service learning project. The core part of this assignment is the design of a hands-on experiment related to an assigned renewable energy technology that is targeted to 4^{th}-7^{th} graders. They work in teams to create a unique way of explaining the technology to middle school age children. At the end of the semester, the San José State University students bring their hands-on modules to the Third Street Community Center's after school program. The Third Street Community Center is walking distance to the university campus and services neighborhood children, most of who are from low income families and/or first-generation immigrant families. The renewable energy modules correlate well with the Third Street Community Center's after school program, which has a science and engineering focus.

The students who enroll in the Renewable Energy Engineering class are passionate about making a difference in society through engineering. One purpose of the service learning project is to build on this passion, giving them a tangible way to get involved while they are students. The project fosters an ethic of civic engagement among the engineering students. This engagement with the community should enhance their engagement with learning and increase their dedication to engineering.[13] The positive effects of integrating service-learning in the curriculum include improved retention and graduation rates particularly among underrepresented groups and women, and a stronger civic ethic among students.[14,15,16]

Students, particularly women and underrepresented groups, cite the ability to make a difference in society as one of the main reasons they choose careers in science and engineering.[17] However, the impact engineers have on society is more commonly viewed from a corporate standpoint (for-profit companies develop products and technologies that positively impact society), and thus STEM service-learning has traditionally been integrated from the corporate perspective; e.g. products to benefit society are designed as part of a course. Community-based service learning opportunities offer alternative ways for science and engineering students to become involved and make a difference in their own communities.

This community-based service learning project is facilitated by two organizations on campus: CommUniverCity and the Center for Community Learning and Leadership. CommUniverCity is a model service-learning collaborative that brings together resources of San José State University, the City of San José, and local organizations to address resident identified priorities. The neighborhood involved in CommUniverCity is the Five Wounds/Brookwood Terrace (FWBT) which borders the San José State University campus. The FWBT neighborhood is one of 19 Strong Neighborhoods Initiative areas identified as distressed by the City of San José

State.[18] It is highly diverse: of approximately 20,000 residents, 66% are Hispanic, 15% are Vietnamese, and 9% are of other racial/ethnic backgrounds. CommUniverCity works with faculty to create, support, and enrich service learning projects to address the community development priorities identified by FWBT residents. The service learning project in the Renewable Energy Engineering class directly targets two of the priorities identified by the neighborhood: to create a college going culture and to increase understanding of science and technology.

CommUniverCity provides the community partnerships for the service learning projects on campus. Infrastructure on teaching pedagogy and assessment are provided by the Center for Community Learning and Leadership. This Center assists faculty in aligning the service project with the learning objectives of the class; maximizing learning opportunities; including resident input in the planning, implemention and evaluation of the project; developing outcome measures; and documenting, analyzing and interpreting outcome data.

Renewable Energy Engineering Class Service Learning Project Details

The students go through several milestones throughout the semester for the Renewable Energy service learning project. First, the students are assigned to a renewable energy technology (such as solar cells or wind power). Students are surveyed on their preferences and teams are assigned that balance the student's choice while also diversifying student majors and level (undergraduate/graduate). Next, students individually write an overview of the technology that references at least three media articles. The goal of this assignment is to build in each student an understanding of the "big picture" issues influencing each technology. Then, students individually write a literature review on a very specific research topic related to the technology. The paper must reference at least three technical journal articles on the same research topic. The goal is to build the level of expertise of the student.

The last phase of the project is for the team to come together and synthesize their different areas of expertise to develop a teaching experiment for middle school age children. This is an open ended assignments and the deliverables student teams have produced over the years have varied significantly. The main requirements students are given are that the project must be hands on with an experiment aspect to it and that the student teams must also create a handout that explains the fundamentals of the technology to the children and their parents. Some examples include: building, optimizing, and racing solar cars; building circuits of solar cells to power lights and toys; building and optimizing designs of solar thermal cookers; building and optimizing water mills; building and optimizing windmills; identifying energy sinks in model houses and reconfiguring the house to reduce energy consumption.

This activity challenges students to think about what they have learned and explain it in language and concepts that a child can understand. The students discover that it is often hard to explain something in simple terms. While any kind of project could be designed that has students synthesize and apply what they learn, the service learning aspect of the project makes the students feel like their effort in creating the project has value and worth. They have contributed something to society beyond just the abstract learning of the material and the intangible benefit to their future engineering career. Table 3 details the three main steps of the service learning project.

Table 3: Components of the service learning project in a Renewable Energy Engineering class.

Individual Overview: Builds awareness of "big picture" context of the technology
Individual Literature Review: Creates expertise in the technology
Team Design of Teaching Experiment: Synthesizes learning and creates a product that is of value to the community
Utilization of Experiment at Middle School Program: Encourages civic engagement and reinforces learning through teaching of material to others

Assessment of the service learning project was done using a summative survey. Students were asked to self report the impact of the service learning project on their understanding of engineering concepts, motivation to work in the field of renewable energy, and commitment to community service. The students reported their answers on a scale of 1 to 5 [5 being the highest: 5 (Strongly Agree), 4 (Agree), 3 (Neutral), 2 (Disagree), and 1 (Strongly Disagree)].

Table 4 lists the survey questions, the average score, and standard deviation from 22 students in Fall 2010. As can be seen from the data, all of the students strongly felt the service learning project increased their understanding of engineering concepts, their motivation for working in the field, and their interest and confidence in helping society.

Table 4: Results of assessment survey of a Renewable Energy Engineering service learning project. Survey was of 22 students in Fall 2010.

Survey Questions	Average	Standard Deviation
The components of the project (introduction, literature review, and Community Center Project) increased my learning of renewable energy.	4.41	0.59
The project increased my motivation of working in the field of renewable energy in the future.	4.27	0.71
The project increased my interest of using engineering to help society.	4.5	0.6
The project increased my confidence in using engineering to help society.	4.41	0.73
Overall, I enjoyed the project.	4.36	0.66

Summary

The burning of fossil fuels and deforestation of the earth are creating an unprecedented increase of CO_2 in the atmosphere. This is correlated with warming of the earth's atmosphere and climate change. Alongside of this challenge, the coming generation is facing a drastic increase in energy demand with a shrinking supply of accessible fossil fuel reservoirs. This is increasing the interest in renewable energy engineering.

Research and manufacturing in renewable energy engineering requires a team of engineers from varying disciplines. Each must be trained in the details of their engineering major but have skills to understand the complex societal, environmental, economic, and engineering aspects unique to renewable energy. The engineer should also have experience working on multidisciplinary teams and a motivation to make a difference in society.

San José State University has developed a general engineering class in Renewable Energy Engineering to accomplish these educational goals. The class covers how traditional energy is produced, measured, and sold; solar thermal; photovoltaics; wind; hydropower; fuel cells; biofuels; geothermal; and ocean, wave, and tidal energy. Active in class exercises are utilized to guide students in building on their prior knowledge, contextualizing the advantages and disadvantages of the technology, applying calculations and engineering fundamentals, and designing solutions.

A major learning exercise in the course is a community-based service learning project where the college students design teaching experiments for middle school children. In the first phase of the project, students individually write an overview of the technology and a literature review. Multi-disciplinary teams of students then synthesize the expertise they gained through these assignments to design a teaching experiment. The teams bring the teaching experiment to a local after school program for middle school children. Facilitation of this partnership is through CommUniverCity, a model service-learning collaborative that brings together resources of San José State University, the City of San José, and local organizations. Integration of the service learning project into the curriculum is facilitated by San José State's Center for Community Learning and Leadership. Assessment of the service learning project show increases in students' self reported understanding of the engineering and their motivation to make a difference in society.

The next generation of engineers is going to play a key role in helping solve our society's crises including rising demand for energy and climate change. Service learning reminds and challenges engineering students that the goal of an engineer is to make a difference in society. Service learning projects allow students to use their enthusiasm now to start making a difference in their community.

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On Exploring the Connection between Hispanic Engineering Students' Educational Goals and Communal Obligations: for Project-Based Learning through Community Engagement

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Abstract

The goal of this research was to acquire a deeper understanding of the perceptions held by Latino/Hispanic engineering students, specifically what factors students associate their educational efforts with and the extent to which their communal goals impact their academic goals. Blending the concurrent nested and sequential designs within a mixed methods approach [4], a variety of research techniques was employed to elicit students' views and attitudes. A focus group of five Latino/Hispanic students was asked about their perceptions and attitudes regarding the climate within an engineering college. From their responses emerged 10 themes, collapsed into six dimensions; these were later used to construct a nine-item survey instrument deployed to over 150 Latino/Hispanic engineering students. In asking whether Latino/Hispanic engineering students felt disconnected to the general student population and to the engineering discipline, the study also investigated the extent to which self-segregation occurred across other ethnic/racial groups. Questions were primarily designed to measure the role that communal obligations play in Latino/Hispanic engineering students' academic success. Initial evidence suggested that Latino/Hispanic students' level of engagement with the broader community can be improved by developing curriculum that focuses on project-based learning situated in their own community. The data also revealed that Latino/Hispanic students were not searching for culturally-based professional organizations to join. This research provides the initial demonstration of the possibility for strengthening URM students' ties to their own communities, even through activities exerted amongst ethnically/racially non-distinct peer groups.

Introduction

According to the *Diverse Issues in Higher Education* publication [8] delineating higher education institutional tributes, California State University, Long Beach (CSULB) was ranked 19th within the top 20 for conferring engineering degrees to minority students and ninth for engineering graduate degrees to Latino/Hispanic students. Despite these accolades, institutional data continues to reveal that a disproportionate number of first-generation students, particularly URM students, continue to fall by the wayside. In 2009, over 50% of engineering undergraduate students who were on or approaching academic probation was of Latino/Hispanic descent [5]. Many intervention programs, principally minority engineering programs, originally derived from the determined work of Landis [16], focus on clustering students in common course sections by ethnic/racial origin and provide a unique study center for URM students. These practices were founded on two assumptions: 1) reducing isolation of URM students so that a sense of camaraderie can be achieved and 2) aggressively directing resources, mentors, and skills learning to ensure access for URM students [16]. Given the fact that Southern California boasts the highest population of Latino/Hispanics in the nation, with many engineering colleges having thriving culturally-based chapters, such as the Society of Hispanic Professional Engineers (SHPE) and Mexican American Engineers and Scientists (MAES), along with increasing student service centers on many college campuses, the assumption that URM engineering students feel more isolated or have less access to services as compared to other ethnic groups perhaps has merit in only those institutions geographically situated in low-minority communities or institutions that lack a student services delivery model.

This greater attention to helping URM students succeed in engineering has motivated many engineering colleges to focus on creating learning communities based wholly on race/ethnicity. In 2007, CSULB was awarded a $2.8 million five-year grant from the Department of Education through its Hispanic Serving Institutions (HSI) Program. The grant focuses on improving the academic advising and mentoring of Latino/Hispanic students by supporting professional development in the area of culturally relevant advising/instructional strategies for Latino/Hispanic students, and working to develop better metrics with which to track the academic progress of Latino/Hispanic students. This considerable level of support has resulted in noticeable increases in enrollment and first-year retention rates, at 80% and 91.3% for Latino/Hispanic freshman and transfer students, respectively [13]. Sustaining Latino/Hispanic students beyond the first year results in increased graduation rates, with 15% for the six-year rates for freshmen and 12.5% for the four-year rates for transfer students [13]. The increased graduation rate of Latino/Hispanic students, now exceeding that of the national average, is praiseworthy. However, the argument that is presented in this paper involves the need to improve the academic quality of Latino/Hispanic students pursuing engineering degree programs; it is not enough that students simply graduate.

When Latino/Hispanic students represent over 50% of engineering undergraduate students who are on or approaching probation [5], we are then forced to ask a different question – what is meant by 'graduation success'? Thus, the operational definition of 'graduation success' begins to shift to a new context in which it is necessary for us to look deeper into the academic experiences of students. How many times do students fall on academic probation? What actions do students take to clear academic probation? Can low-completion rate courses be re-developed to align to those culturally relevant strategies known to enhance Latino/Hispanic students' academic success? These are among a host of questions that have not yet been explored when examining 'graduation success' in the context of the academic quality of students.

The practice of clustering URM students by racial/ethnic origin continues to persist, and the precepts founded on social identity theory provide the rationale for minority engineering programs to justify the need for URM students to experience 'oneness' within a group of individuals. According to social identity theory, individuals naturally align themselves within groups or categories based on any number of social constructs [22, 23, 24]. And although social identification provides individuals with a sense of belonging and contributes distinctiveness in cases where social prestige characterizes the group, the risk for developing self-indemnifying behaviors as a result of social stigmas is attached to some group formations. The research of Cheryan and Plaut [3] indicates that students who struggle in the STEM fields do not envision similarity between themselves and the STEM professionals whom they aspire to be. Fittingly, many programs seek role models who embody students' racial/ethnic backgrounds in order to cultivate a sense of belonging and cultural pride. However, stereotypic threat [21] and spotlighting theory [17] warn against a climate of over-representation wherein homogeneity within a group is established. Owing to millennial students' more tolerant attitude toward diversity [14], the practice of ethnic/racial clustering may in fact have negative effects as it further accentuates students' differences and isolates subgroups of students from the general student population.

It is clearly recognized that the practice of ethnic/racial clustering was originally conceived to help URM students, but in California, a state that has no majority ethnic group and often referred to as a 'minority-majority' state, with Latino/Hispanics comprising 37% of California's population [20], this practice becomes impractical. As the demographic landscape of the American workforce continues to change dramatically, the long-term success of engineering professionals must begin with early opportunities for students to develop the ability to work with a multiplicity of people from various backgrounds, ethnically, racially, and otherwise; the concept of diversity then takes on multiple dimensions. For this reason, widely held sentiments emphasize the need to create heterogeneity in engineering student groups so that individuals are able to develop a sense of diversity within an inclusive environment.

Defining the Problem

The supposition that lack of perceived similarity affects the level of career interest and identity development of Latino/Hispanic engineering students prompts minority engineering programs to arrange for ethnically/racially-themed activities and events. These programs though well-intentioned, aim less at improving math skills or engineering career awareness as much as they are valued for instilling students' personal confidence, soft skills, and camaraderie within an environment of racially/ethnically like peers. Even while the dictum of these programs is to 'recruit and retain more under-represented minorities', few activities connect students to what is being taught within the engineering classroom or increase faculty-student interaction. Hence, feelings of disconnectedness may actually point to students' detachment from the curriculum – and not as a result of feelings of isolation or loss of cultural identity.

Given the CSULB data on the current academic performance of Latino/Hispanic engineering students [5], including those who are doubly served through other student services programs (where provided are nurturing environments and additional resources), more research is needed to determine why a majority of Latino/Hispanic engineering students continue to decline academically even when a full complement of minority engineering program services is rendered. One particular finding from the 2007 program review of the CSULB MESA Engineering Program (MEP) describes students' reluctance to study within their culturally-defined groups [6]. Another finding from this same review revealed that within a listing of 165 URM students purportedly being served by MEP, only 26 students identified themselves as "active members of MEP" [6]. More disquieting is the data drawn from a 2009 report of MEP students who were on or approaching academic probation; the data revealed that MEP students who were on probation had a 25% higher likelihood of disqualification than those who did not participate in the program. URM students, specifically Latino/Hispanic students who were not served by MEP, were able to clear and stay off of academic probation at a higher rate as served by the college's "Engineering Early Identification & Monitored Probation" program. Comparing these two groups of Latino/Hispanic students (those served by MEP and those not served by MEP), clearly those who were not part of MEP had opportunity to observe students of other ethnic/racial backgrounds who were in similar academic peril. Specifically, in the academic probation awareness workshops, non-MEP Latino/Hispanic students sat in a racially/ethnically mixed group. However, those being served by MEP seek the assistance of an MEP counselor. While this observation may seem inconsequential, the greater effect that it engenders is reducing the stigma currently attached to URM engineering students.

These findings raised concerns about the program's ability to foster the professional identity and improve the retention of URM students; it questioned the efficacy of the clustering practice. To-date, no causal relationships exploring the impact of these strategies on student success are available. Despite these issues, there is value in incorporating students' cultural experiences as an element of their academic development. Beyond this assertion, there is little recognition of the worth of ethnic/racial clustering as a retention strategy for URM students.

Theoretical Framework

The theoretical framework underpinning this research study is derived from previous studies that correlate communal goals and obligations of students with academic performance. Research conducted by Brown [2] determined that there were culturally connected reasons for why there was an under-representation of African-American students who chose to pursue veterinary medicine careers. The research done by Umana-Taylor [25, 26] revealed that individuals who express specific cultural orientations are more concerned about their communal goals and consider such goals to be more important, as compared to individuals who do not present any cultural orientation; these include individuals who identify themselves as Caucasian or non-Latino/Hispanic White. According to LaFromboise and Foster [15], Latino/Hispanic students, more than any other racial/ethnic group, express a greater inclination toward communal culture [14]. With a preponderance of research attesting to Latino/Hispanic students' valuation of community, engineering programs should attempt to develop project-based learning models that benefit the Latino/Hispanic community. Westerman [27] believes that by prioritizing the community within the context of classroom learning, Latino/Hispanic students can thrive academically knowing that their efforts will directly serve their community. These previous studies investigate Latino/Hispanic students' overall perspectives on learning, but there continues to be a gap in literature on Latino/Hispanic students' perspectives of the valuation of community as it relates to their own learning within an engineering program. It is the intent of this study to provide preliminary data on how Latino/Hispanic engineering students relate their education to their obligations to their family and their community.

Phase 1: Qualitative Approach

Focus Group. This study attempted to deepen the understanding of how Latino/Hispanic students' family-focused culture could be used to positively impact their academic performance in engineering programs, but being able to succinctly measure responses based on this notion is difficult. Since disseminating a survey inquiring about students' perceptions of race/ethnicity is a sensitive affair, applying a focus-group approach to procure underlying assumptions held by the author was an ideal approach. Moreover, as the focus of the study involved investigating Latino/Hispanic students' perceptions, it was important to create a survey based on the sentiments of Latino/Hispanic students. Thus, the focus group involved Latino/Hispanic students; the decision to create a survey based pragmatically on using representative viewpoints for question formation was warranted. For survey construction, only a small representative sample of five to nine participants is needed; this conforms to Morgan's recommendation for using focus groups for qualitative research [18]. Five Latino/Hispanic undergraduate engineering students (three male and two female) volunteered to participate in the focus group; the students were recruited from those active in leadership roles.

Trigger questions (see Table 1) from a prior semi-structured interview protocol were used to encourage candid discussion amongst the group, but they were not tightly defined; opportunity arose for follow-up questions to emerge during the discussion. The group was asked to speak freely about their student experiences within an engineering degree program. To avoid introducing bias, the author made no references to Latino/Hispanic ethnicity, race, or culture and allowed the group to establish topics as free and original. Neither the term "community" nor the phrase "communal obligation" was explicitly voiced by any member of the focus group, but the notion of "community" is implied in the narratives and extended to synonymous expressions, such as "my family's tradition", "my neighborhood", and "my tradition".

Table 1. Trigger Questions for Focus Group

- What has been your experience here in the College of Engineering at CSULB? Are there any experiences that you consider memorable, either pleasant or unpleasant?
- Who are the colleagues with whom you study? How did you come to identify these colleagues with whom you study? Do you spend time outside of class with these colleagues?
- What importance do you place on people's backgrounds and cultural experiences? Do you feel more comfortable being around people who share similar interests, goals that you have?
- What does your family mean to you? Are you involved in any family activities?

Analysis and Results

The responses from the focus group were inputted into and transcribed using NVivo 8, a qualitative data analysis software. Generally, the interpretive nature of qualitative data requires a second reviewer; however, since the focus group was convened for the explicit goal of creating a survey instrument, the author felt that the process of theme identification could be accomplished by members of the focus group. Thus, a participatory design approach was used, rather than the traditional method of involving research assistants/reviewers. Themes derived from the open-ended discussion were repeatedly reviewed and distilled using the thematic content analysis approach as described by Glasser and Strauss [11]. With each member and the author using an iterative line-by-line open-coding technique, all narratives were coded and a set of ten consistent themes was generated. As the focus group vacillated between their understanding of ethnicity/race, culture, family and community, and finding that there were similarities in the ten themes, a last review resulted in collapsing the themes into six dimensions: *Culture and Heritage*, *Family Obligation*, *Family Pride and Shame*, *Family Influence/Pressure on School*, *Importance of Community*, and *My Community is Who I am*. The qualitative analysis phase of this study was based on an incredibly complex and laborious process but resulted in some remarkable and unexpected responses. Table 2 shows the themes, their corresponding dimensions, and some sample statements.

Table 2. Dimensions and Themes Generated from Focus Group Discussion

Dimensions and Themes	Sample Statements
1. *Culture and Heritage* • Culture and Heritage	"My family's tradition is important to me because without it, I don't have culture".
2. *Family Pride and Shame* • Family Pride and Shame	"My father would be ashamed of me if I didn't do well in school".
3. *Family Obligation* • Family Obligation • Giving Back to My Family • Giving Back for Sacrifices Made	"He works very hard for me and made sacrifices".
4. *Family Influence/Pressure on School* • Family Influence/Pressure on School	"I have to do well even if I need to give up some things". "My mom wants me to be an engineer, and I want to succeed to help her".
5. *My Community is Who I am* • My Community is Who I Am	"Even if I was really rich, I think I would still like to stay close to where I grew up".
6. *Importance of Community* • Importance of Community • Giving Back to the Community • Engineering Will Help My Community	"There are so many things that we could do to help improve my neighborhood". "I think about all the sacrifices my people made for me to be here, so I almost feel like I need to give something back". "Where I live, there are many projects needing to be improved"

Question Formation and Survey. The six dimensions guided the construction of a nine-item survey (see Appendix). To increase the likelihood that participants would grasp the intended meaning of the survey items, word choice was a balance between the author's understanding of survey construction and vocabulary sought by the focus group. The questions were revised numerous times to ensure that no underlying opinions existed. It is noted that even though the nine survey items include eight statements and one actual question, the items are being referred to as 'questions' since they tend to *ask* students. For ease of reference, the nine items will be referred to as *Q1, Q2, Q3*, etc., in the ensuing data tables and graphs.

Phase 2 – Quantitative Approach

Within the College of Engineering at CSULB, all freshmen are required to enroll in three 1.0-unit introductory engineering courses, ENGR101 ("Introduction to Engineering Profession"), ENGR102 ("Academic Success Skills"), and one of seven discipline-specific courses. These courses provide a 'captive audience' and offer opportunities for varied and multiple interactions between faculty and students. Survey participants were from nine sections of ENGR101.

Participants

Participants were identified within a convenience sample drawn from all freshmen enrolled in ENGR101 in the Fall 2010. Since a 'captive audience' was readily accessible, the nine items were incorporated into the existing ENGR101 'exit' survey and deployed at the semester's end. As race/ethnicity questions are immaterial to course curriculum, students were given the option of completing the survey, referred to as "Family & Communal Obligations", as extra credit (see Figure 1 below). From a total of 527 freshmen, 416 (78.9%) students responded to the survey. Even though the study focused on examining Latino/Hispanic students' perceptions of race/ethnicity in the context of an engineering program, the survey was administered to all freshmen so that across-group comparisons can be made. Data will be archived for future comparative analysis [19], and common aspects between student cohorts may also be studied.

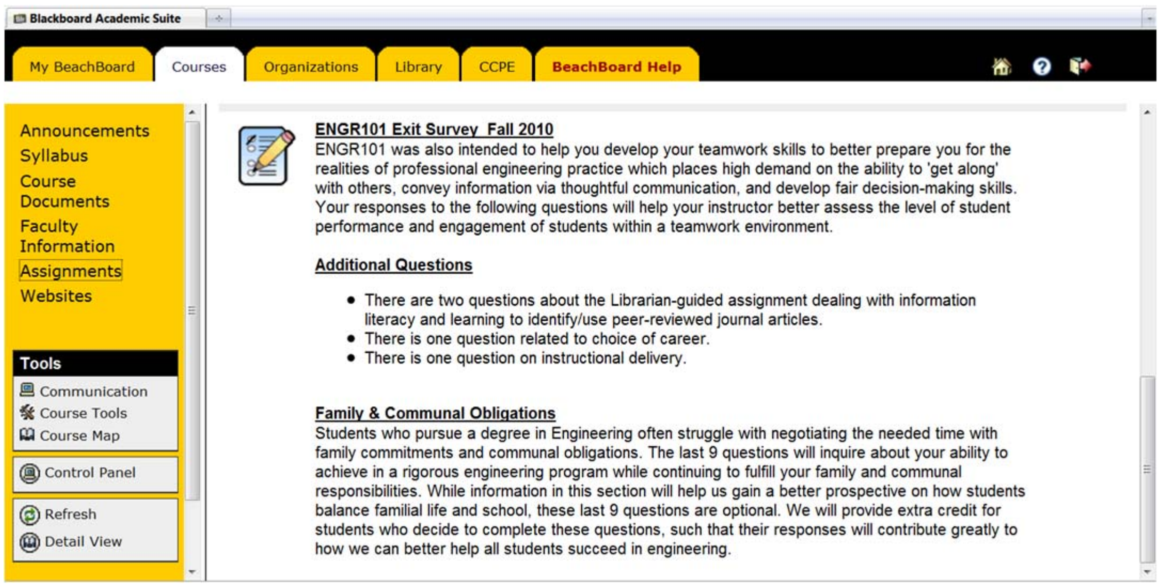

Figure 1. Screenshot of "Family & Communal Obligations" survey via CSULB BeachBoard.

Analysis and Results

The total racial/ethnic breakdown of 416 respondents is: 28.1% Asian, 23.3% Caucasian, 3.6% African American/Black, 36.1% Latino/Hispanic, 6% Multicultural, and 2.9% 'Other' (American Indian = 0.5%; Middle-Eastern = 1.2%; Native Hawaiian or Other Pacific Islander = 1.2%). Because the ethnic/racial group composing 'Other' is different and small in number, analysis was limited to five groups: African American/Black, Asian, Caucasian, Latino/Hispanic, and Multicultural.

Table 3. Demographic Breakdown of Respondents

Racial/Ethnic Group	# of Students
American Indian	2
Asian	117
African American/Black	15
Caucasian	97
Latino/Hispanic	150
Middle Eastern	5
Native Hawaiian or Other Pacific Islander	5
Two or more ethnic/racial backgrounds	25
Total	416

Asian, African American/Black, and Latino/Hispanic populations are featured because they express specific cultural orientations and are deemed ‘in-groups’. Caucasian students are included because they do not typically express any cultural orientation; as an ‘out-group’, they contrast against in-groups. Tables 4-12 show response frequencies for each question.

Table 4. Responses to Q1

	Asian	African American/Black	Caucasian	Latino/ Hispanic	Total
Always	38	2	34	52	126
Sometimes	72	9	30	70	181
My family does not celebrate cultural heritage traditions/events.	7	3	30	14	54
Unanswered	0	1	3	14	18
Total	117	15	97	150	379

Table 5. Responses to Q2

	Asian	African-American	Caucasian	Latino/ Hispanic	Total
Always	19	5	15	29	68
Sometimes	77	6	39	77	199
Never	14	0	10	19	43
I do not have any cultural/heritage activities or events.	7	4	33	15	59
Unanswered	0	0	0	10	10
Total	117	15	97	150	379

Table 6. Responses to Q3

	Asian	African American/Black	Caucasian	Latino/ Hispanic	Total
Yes – Absolutely!	45	3	26	47	121
My family is only one reason for my motivation to succeed.	46	9	39	65	159
Not really	21	3	24	19	67
I do not care what my family thinks.	5	0	8	8	21
Unanswered	0	0	0	11	11
Total	117	15	97	150	379

Table 7. Responses to Q4

	Asian	African American/Black	Caucasian	Latino/ Hispanic	Total
Yes – Absolutely!	77	11	37	64	189
My family will be proud of me even if I fail.	18	1	29	36	84
Not really	18	3	27	32	80
I do not care what my family thinks.	4	0	4	7	15
Unanswered	0	0	0	11	11
Total	117	15	97	150	379

Table 8. Responses to Q5

	Asian	African American/Black	Caucasian	Latino/ Hispanic	Total
Yes – Absolutely!	51	9	23	75	158
My family will benefit from my success.	55	6	42	58	161
I am undecided about how my family fits into my future career success.	6	0	22	2	30
My success will be for my sole benefit.	5	0	10	4	19
Unanswered	0	0	0	11	11
Total	117	15	97	150	379

Table 9. Responses to Q6

	Asian	African American/Black	Caucasian	Latino/ Hispanic	Total
Yes	6	1	3	4	14
Yes – But I am having second thoughts.	7	2	4	5	18
My parents did not heavily influence my career choice.	35	3	28	18	84
My career choice was my own.	69	9	62	112	252
Unanswered	0	0	0	11	11
Total	117	15	97	150	379

Table 10. Responses to Q7

	Asian	African American/Black	Caucasian	Latino/ Hispanic	Total
More emphasis on engineering innovation	98	12	74	100	284
More emphasis on engineering research	4	2	18	14	38
Community-based projects (serving *my* own racial/ethnic community)	5	1	0	6	12
Community-based projects (serving *any* racial/ethnic community)	10	0	5	18	33
Unanswered	0	0	0	12	
Total	117	15	97	150	379

Table 11. Responses to Q8

	Asian	African American/Black	Caucasian	Latino/ Hispanic	Total
Not Applicable – I do not have any communal obligations.	7	2	30	11	50
Not Important	6	0	14	9	29
Somewhat Important	38	3	30	45	116
Important	45	7	17	50	119
Very Important	21	3	5	24	53
Unanswered	0	0	1	11	12
Total	117	15	97	150	379

Table 12. Responses to Q9

	Asian	African American/Black	Caucasian	Latino/ Hispanic	Total
Yes - That statement is true, and I want to promote my culture.	21	9	3	55	88
Yes - I am part of a culturally-based engineering student organization but only for socialization purposes (not culture).	11	3	3	14	31
Yes - I am part of a culturally-based engineering student organization but only for exploration purposes (I am not of that culture).	16	0	3	9	28
No - I am not interested in joining culturally-based engineering student organizations.	57	2	64	42	165
No - I do not believe in culturally-based engineering student organizations (I think only major-based student organizations are acceptable).	12	1	23	19	55
Unanswered	0	0	1	11	12
Total	117	15	97	150	379

Descriptive Analysis

While responses for all students were collected, this study seeks to investigate perceptions held by Latino/Hispanic students. Hence, in this section graphs are provided for Latino/Hispanic respondents with the subsequent analysis pertaining specifically to this group.

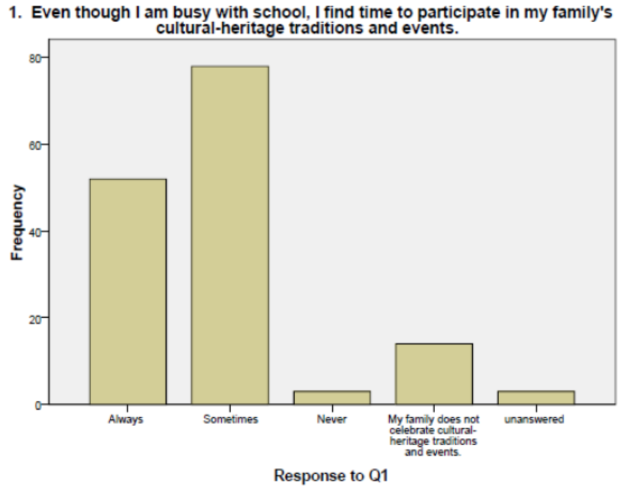

Figure 2. Latino/Hispanic Responses to Question 1.

Question 1 asked students to consider their family obligations given a busy school situation. Data revealed that a majority (81.3%) of students continue to find time to engage in cultural-heritage traditions of the family. 34.7% responding that they "Always" put cultural-heritage traditions before school while the greater majority (46.7%) responded that they "Sometimes" found the time for honoring their traditional practices.

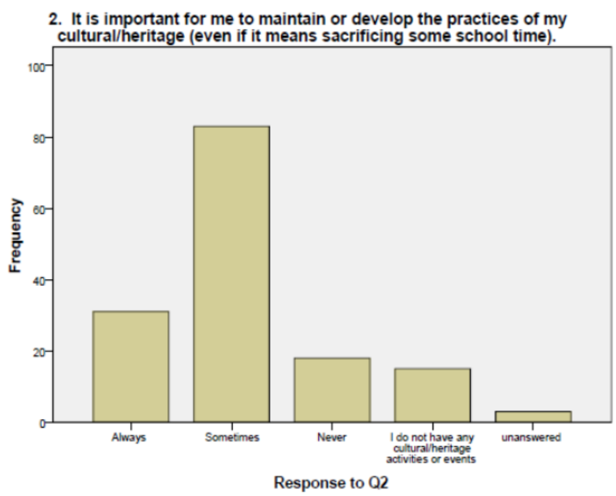

Figure 3. Latino/Hispanic Responses to Question 2.

Knowing that Latino/Hispanic students place value on culture/heritage, Question 2 investigated whether prioritization and pre-occupation of culture/heritage encroached on school time. The data showed that a small percentage (19.3%) would forfeit school time in lieu of cultural/heritage practices while a greater majority (51.3%) would "Sometimes" sacrifice school time. 19 students (12.7%) reported that they would "Never" sacrifice school time. Upon closer inspection of these 19 students, it was discovered that they entered CSULB at the college-math ready level with 15 students placing at Calculus I. While no correlation between devaluation of cultural/heritage practices and academic aptitude is being made here, future analysis may determine to what extent prioritization and pre-occupation of cultural/heritage duties impinge on students' ability to commit time needed for a successful engineering academic experience.

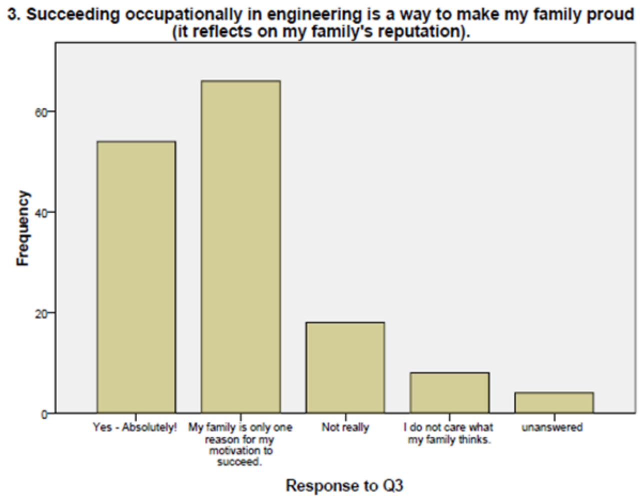

Figure 4. Latino/Hispanic Responses to Question 3.

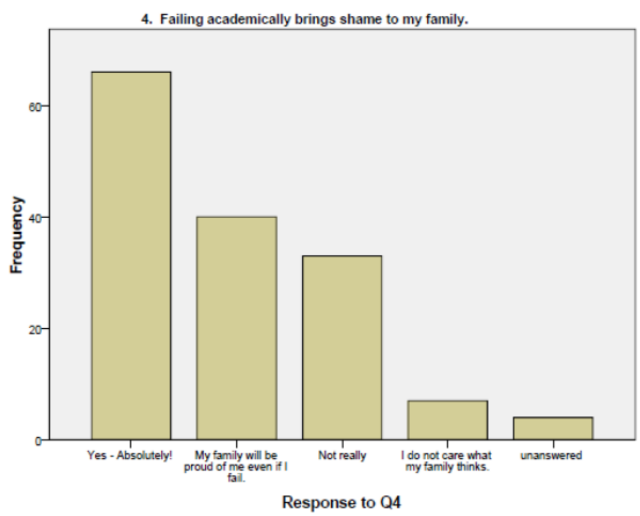

Figure 5. Latino/Hispanic Responses to Question 4.

Unlike Question 1 and 2 (which were developed on the dimension of *Culture and Heritage*), Questions 3 and 4 were conceived based on the dimensions of *Family Obligation* and *Family Pride & Shame*, respectively. Students thought about the relationship between engineering career success and the family's reputation; they contrasted this idea against how academic failure might affect their family. A majority of students (74.7%) reported that engineering career success would bring pride to their family. 4.67% of students reported that they were unconcerned about their family's reaction to either their success or their failure in an engineering career.

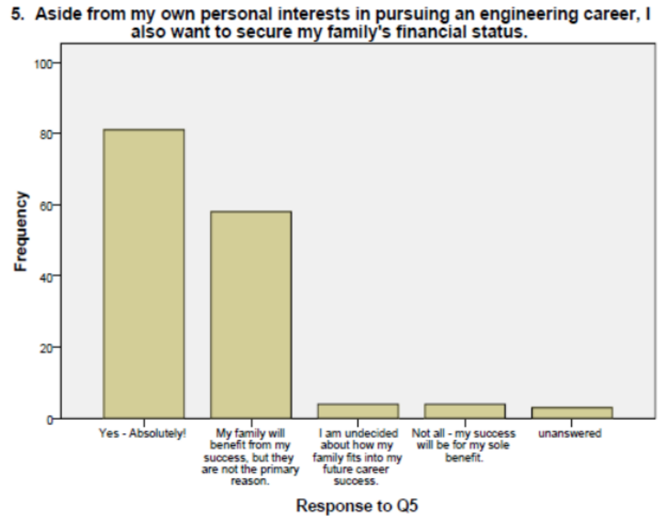

Figure 6. Latino/Hispanic Responses to Question 5.

In examining how students balance engineering career interests against supporting their families, 133 (88.7%) students reported that their career plans were aligned to plans for financially supporting their families. Only 4 students reported that they would benefit solely from their engineering career success; it is not known whether these students were living independent of their families. When students have dual purposes in the construction of their life careers, such that they want to strive beyond self-benefit and ensure their families' success, there is bound to be conflict between career and family. The career motivation of students caught in these predicaments is questioned. Fuligni [10] describes the urgent sense of obligation that is linked to higher academic motivation driven specifically by family responsibilities.

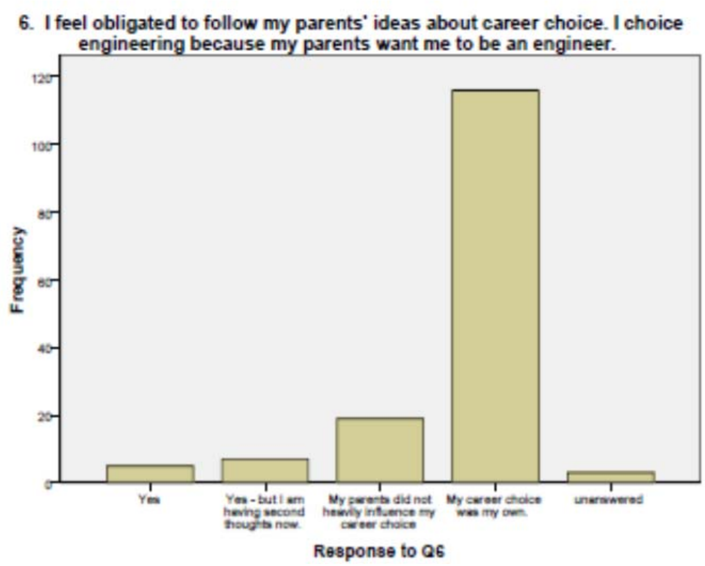

Figure 7. Latino/Hispanic Responses to Question 6.

On the topic of parental influence and pressure on career choice, Question 6 asked students to specifically report how they arrived at their particular career choice. 112 (74.7%) students reported that their career choice was not influenced by their parents. 27 (18.0%) students reported that their parents did have an influence on their career choice; 9 reported that their career choice was their parents' choice, and 18 students reported that their parents were involved in their career choice but not to a great extent. Interestingly, Latino/Hispanic students' response to this question heavily contrasted against Asian students' response. 48 (41.0%) Asian students reported that their parents contributed to their career choice, as compared to 27 (18.0%) for Latino/Hispanic students.

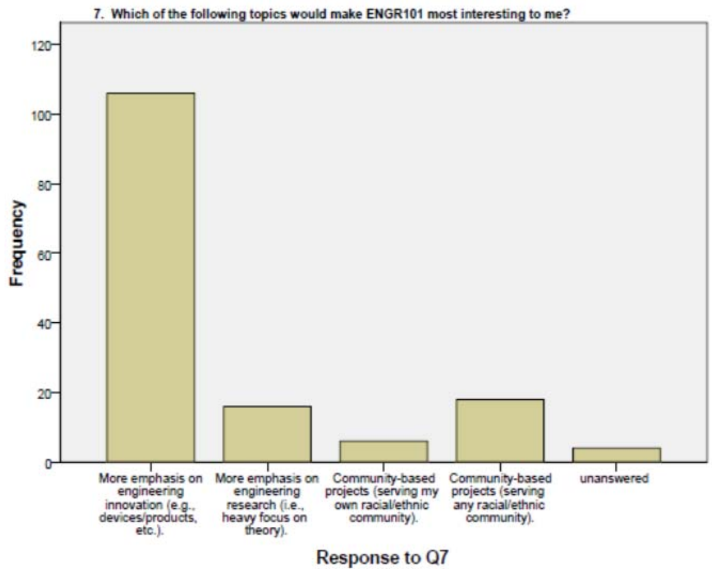

Figure 8. Latino/Hispanic Responses to Question 7.

Question 7 asks students to reflect on their ENGR101 classroom experience and assign importance to four curricular areas. 100 (66.7%) students reported that more emphasis should be given to engineering innovation and less to community-based projects. Initially, these results appeared to conflict with the previous trends that ascribe Latino/Hispanic students' inclination toward aligning career goals with communal goals. Upon further reflection, it is recognized that students might possibly be responding to this question based on the existing curricular and time allotment parameters of the ENGR101 course. ENGR101 is a 1.0 unit course that meets once per week, and for this reason, there is limited opportunity for any long-term project. It was the intent of the study to discover an alternative curricular experience model for Latino/Hispanic engineering students. However, as phrased, this question could not offer reliable data from a descriptive analysis outlook. Despite this, the other questions provided significantly sound data, with some questions submitted to statistical analysis. Taken together, the results are worthy and substantiate the need for major curricular changes.

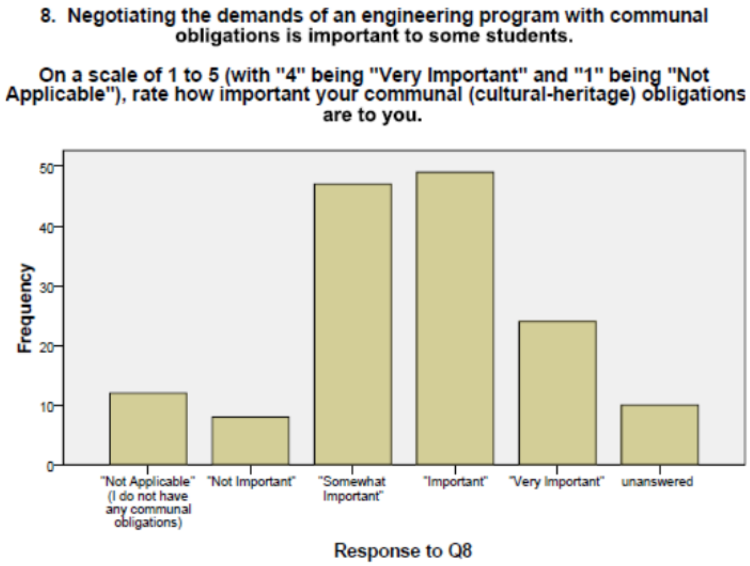

Figure 9. Latino/Hispanic Responses to Question 8.

Question 8 asked students to rate the level of importance that communal obligations have for them in the context of their engineering school life. With 119 (73.3%) of students ranking communal obligations as being important, it is plausible that some of the academic failures seen in the Latino/Hispanic engineering students might be attributed to an inability to negotiate communal obligations with the demands of an engineering program. However, it is also possible that responses to this question may be over inflated by students' interpretation of the question; the original construal of the statement really seeks to find out how students rate the importance of communal obligations given the rigor of their engineering program (i.e., *How important are communal obligations given that you must now commit time for your engineering program*?). The breakdown of ratings within this response is also telling; 45 "Somewhat Important"; 50 "Very Important"; 24 "Important". With the greater majority (62.2%) expressing importance, as opposed to "Somewhat Important" (20.2%), it is believed that Latino/Hispanic students consider communal obligations important even as they dedicate time for their engineering program. 9 students (6.0%) believed communal obligations are unimportant, and 11 (7.3%) reported that they had no communal obligations.

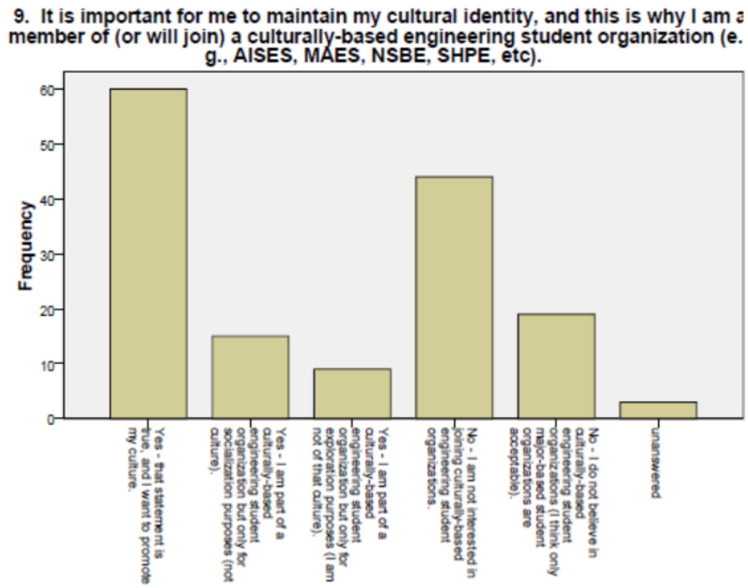

Figure 10. Latino/Hispanic Responses to Question 9.

Reponses for Question 9 are provocative in nature; they reveal that most students expressed less interest in joining culturally-based engineering organizations. 55 (36.7%) students expressed cultural pride as reasons for their participation, while 14 (9.30%) students participating in culturally-based engineering organizations reported that they do not attach any cultural meaning and joined only for socialization purposes. 9 (6.0%) students reported that they currently participate in a culturally-based engineering organizations that is different from their own culture (e.g., NSBE). 61 (40.7%) students reported that they do not intend to join any culturally-based engineering organizations or that they disapproved of culturally-based engineering organizations.

When compared across racial/ethnic populations, Question 9 was endorsed by Latino/Hispanic students more than the other racial/ethnic groups; this implies that the other racial/ethnic groups expressed even less interest in these culturally-based engineering organizations. These responses are noteworthy in light of sentiments regarding the practical value of racially/ethnically segregated activities within an engineering program.

Statistical Analysis

While the previous section provided a wholly descriptive analysis of resultant data, this section offers statistical analysis to validate some assertions made in the previous section. Since the majority of questions were not constructed psychometrically, two inferential statistics techniques were applied. Questions 1, 2, and 8 used a Likert-scale response, and it was possible to treat these data pools as an interval scale. Questions 3 through 7 and Question 9 all involved nominal responses; because of this, they were submitted to separate Chi Square Analyses.

Questions 1, 2, and 8 were submitted to separate one-way Analyses of Variances (ANOVAs) using Race/Ethnicity as the independent variable. F-test statistic, MSE (Mean Sum of Square Errors), and p values (statistical probability measuring consistency between observed results and "pure chance" explanation) were computed for each of the data pools.

For Question 1, which states, “Even though I am busy with school, I find time to participate in my family's cultural/heritage traditions and events” (1= always, 2 = sometimes, 3 = Never), there was a significant effect of Race/Ethnicity, $F(4,385) = 6.27$, $MSE = 0.93$, $p < .001$ (see Figure 11 below for means).

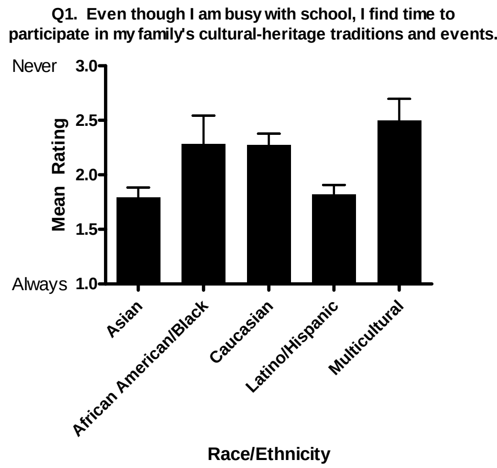

Figure 11. Question 1 Mean Ratings.

Bonferroni pairwise comparisons were conducted with an alpha-level set at .05 for significance. The data showed that both Latino/Hispanic and Asian students were more likely to find time to participate in their family cultural heritage traditions and events as compared to Caucasian and Multicultural students. There was no difference between Latino/Hispanic and Asian students in their willingness to find time for cultural events. While African American/Black students also express affinity for cultural events, the significant effect of Race/Ethnicity on this group is constrained by their small numbers (with students representing only 3.61% of total respondents).

For Question 2, which states, “It is important for me to maintain or develop the practices of my cultural/heritage - even if it means sacrificing some school time” (1= always, 2 = sometimes, 3 = Never), there was a significant effect of Race/Ethnicity, $F(4,389) = 5.89$, $MSE = 0.86$, $p < .001$ (see Figure 12 below for means).

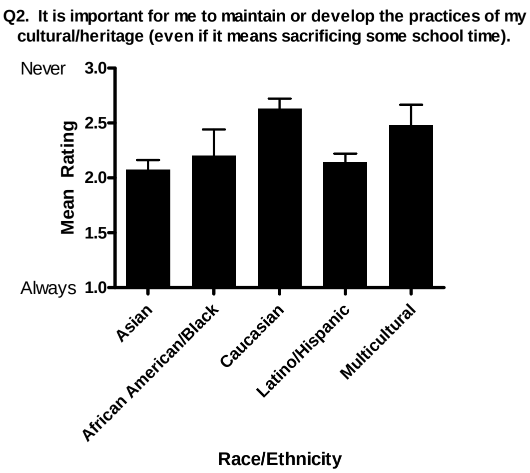

Figure 12. Question 2 Mean Ratings.

Bonferroni pairwise comparisons showed that both Latino/Hispanic and Asian students found it more important to maintain and develop cultural heritage traditions and events as compared to Caucasian students. There was no difference between Latino/Hispanic and Asian students in their rating of the importance for maintaining their cultural heritage.

For Question 8, which states, "Negotiating the demands of an engineering program with communal obligations is important to some students" (5 being "Very Important" and 1 being "Not Applicable"), there was a significant effect of Race/Ethnicity, $F(4,387) = 15.47$, $MSE = 1.29$, $p < .001$ (see Figure 13 below for means).

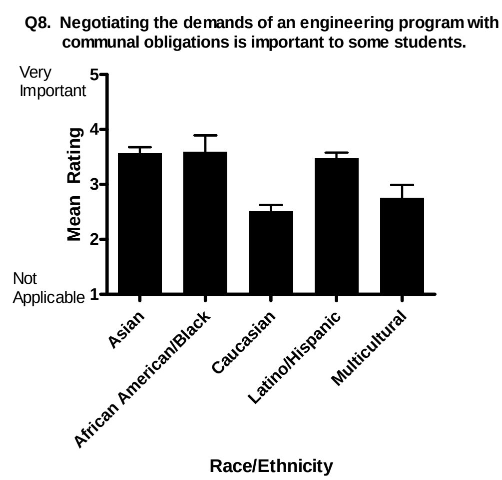

Figure 13. Question 8 Mean Ratings.

Bonferroni pairwise comparisons showed that Latino/Hispanic, Asian, and Black/African American students found it more important to negotiate the demands of an engineering program with communal obligations as compared to Caucasian students. There were also significant differences between Asian and Multicultural students, Latino/Hispanic and Multicultural students, where both Asian and Latino/Hispanic students felt it was more important to include communal obligations than did Multicultural students. Again, there was no difference in ratings between Asian and Latino/Hispanic students.

Unlike Questions 1, 2, and 8, Questions 3 through 7 and Question 9 involved nominal responses. Hence, frequencies for each question were tabulated and submitted to separate Chi Square Analyses to determine whether the pattern of responses differed for each question as a function of Race/Ethnicity.

For Question 3, which stated, "Succeeding occupationally in engineering is a way to make my family proud (it reflects on my family's reputation)", there was no difference between groups, χ^2 (12) = 11.6, $p > .05$.

For Question 4, "Failing academically brings shame to my family", showed a difference between groups, χ^2 (12) = 32.16, $p < .01$ (see Figure 14 below). Asian students were much more likely to indicate that failure brings shame to their family more than any other students. Latino/Hispanic students were next to indicating that their failure would bring shame to the family.

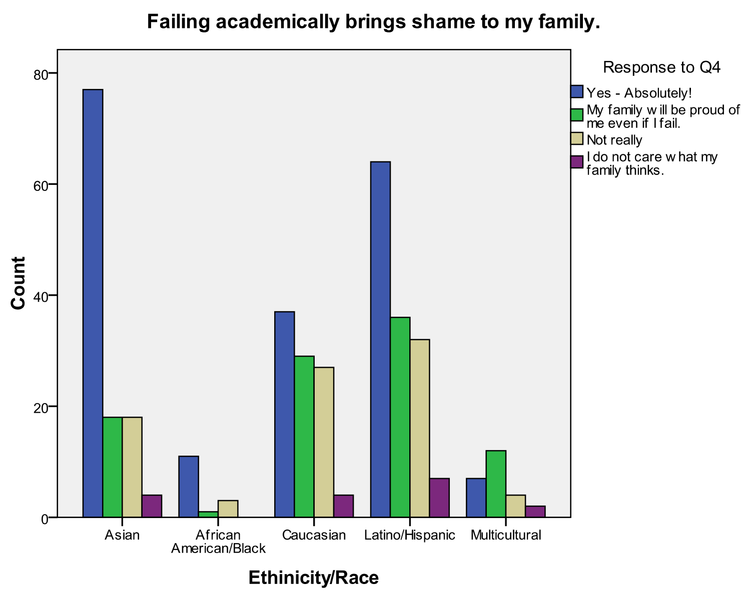

Figure 14. Question 4 Responses and Ethnicity/Race.

For Question 5, which stated, "Aside from my own personal interests in pursuing an engineering career, I also want to secure my family's financial status", there was also a difference between groups, χ^2 (12) = 60.01, $p < .01$ (see Figure 15 below). Here, Latino/Hispanic students were much more likely to indicate that they wanted to secure their family's financial status, whereas Asian and Caucasian students indicated that their family would benefit from their success but that family status was not the primary reason for why the student was pursuing engineering.

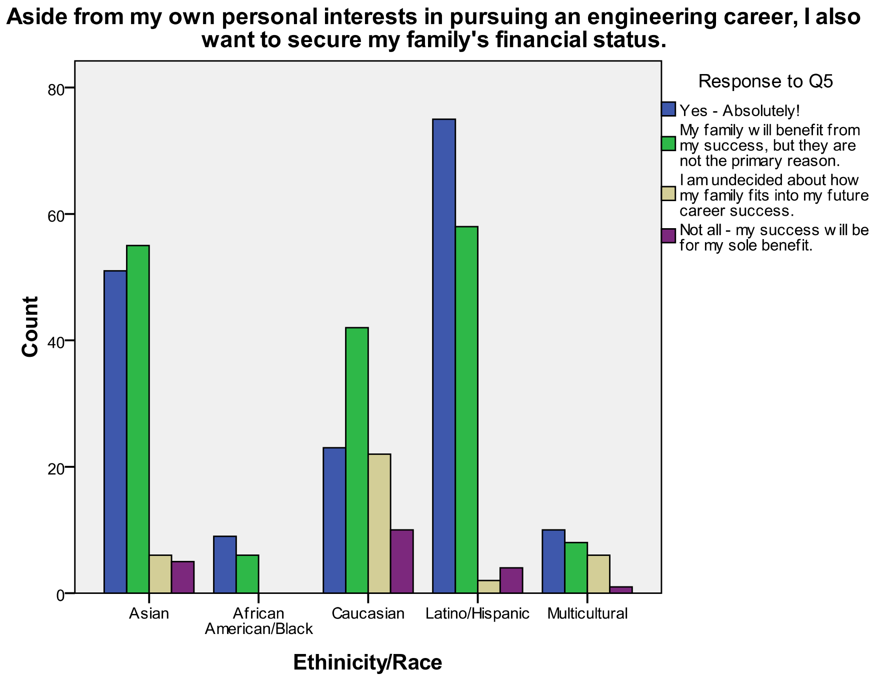

Figure 15. Question 5 Responses and Ethnicity/Race.

For Question 6, which stated, “I feel obligated to follow my parents' ideas about career choice. I chose engineering because my parents want me to be an engineer”, there was no difference between groups, χ^2 (12) = 20.89, $p > .05$. Most students in all racial/ethnic groups indicated that their career choice was of their own choosing.

For Question 7, which stated, “Which of the following topics would make ENGR101 most interesting to me?”, there was a difference between groups, χ^2 (12) = 26.31, $p < .05$ (see Figure 16 below). All racial/ethnic groups felt that more emphasis should be placed on engineering innovation (e.g., devices/products, etc.). However, Asian and Latino/Hispanic students indicated that community-based projects serving their own race/ethnicity as well as any community was also important. The interest in community-based projects in any community was also shown by Caucasian and Multicultural students.

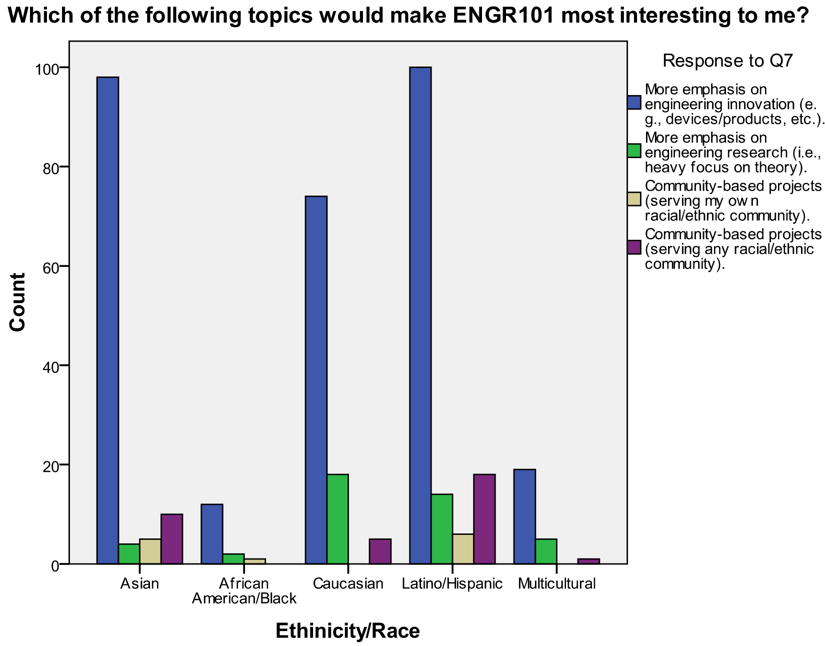

Figure 16. Question 7 Responses and Ethnicity/Race.

Finally, for Question 9, which stated, "It is important for me to maintain my cultural identity, and this is why I am a member of (or will join) a culturally-based engineering student organization (e.g., AISES, MAES, NSBE, SHPE, etc.)", there was a difference between groups, χ^2 (12) = 99, $p < .001$ (see Figure 17 below). This statement was more strongly endorsed by the Latino/Hispanic students than the other racial/ethnic groups. However, most students, regardless of ethnic/racial group, indicated that they were not interested in joining culturally-based engineering organizations.

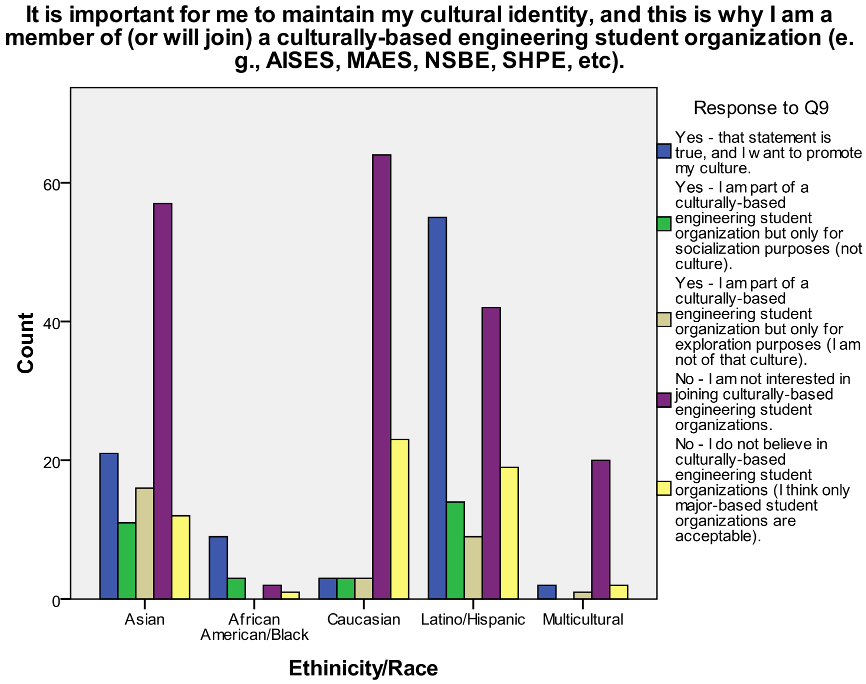

Figure 17. Question 9 Responses and Ethnicity/Race.

Limitations

Appreciating the opportunity afforded by the gap in literature on Latino/Hispanic engineering students' inclination toward aligning educational and career goals with commitments to the family and the community, this study attempted to generate some preliminary data on the topic. By convention, gaps in literature are best filled by first using the qualitative approach to discover what views individuals hold on some aspect of human phenomenon (Creswell, 2007). Yet unlike traditional empirical research, there is no prescribed way to do qualitative research (Morse, 1991). Even with a mixed methods approach (using qualitative data to drive quantitative design), intending to generate sizeable data needed for inferential analysis, researchers must be conservative about making generalizations – even when statistical significance is achieved. Also, within the same racial/ethnic group, variations in student responses to academic settings are constrained by multiple factors (e.g., socio-economic strata, parents' educational attainment, institutional climate, etc.); this makes research in this area complex. Student perspectives at other institutions may diverge quite dramatically from those expressed by the populations examined in this study. Accordingly, the results of this study, while significant, are generalized to a distinct population of Latino/Hispanic students residing in the Southern California region.

Conclusion

The qualitative analysis of the nine survey questions examined Latino/Hispanic students' perspectives on how communal goals competed with career goals, while the statistical analysis validated the significant effect of race/ethnicity on all students' responses to the questions. In this respect, the statistical analysis provided a contrasting view of Latino/Hispanic students' perspectives against those of other ethnic/racial groups' perspectives; there is ample room for future analyses. Taken together, the results of this study revealed that Latino/Hispanic engineering students: 1) place high value on the community, 2) strive to ensure the family's economic standing and status, 3) indiscriminately negotiate school time with cultural/heritage obligations, and 4) impartially participate in culturally-based engineering student organizations.

On the topic of ethnic/racial self-segregation by Latino/Hispanic students, this study revealed that about half (36.7%) of Latino/Hispanic students reported in-favor of and the other half (40.7%) reported disfavor of culturally-based engineering organizations. With students clearly expressing reticence about convening in groups based on their culture, engineering programs should avoid actively segregating students via the clustering practice or in any other way for that matter; students do this naturally and on their own. More importantly, spaces formerly dedicated to minority engineering students should manifest a physical façade that welcomes all students; doing so will reduce the stigma currently attached to minority engineering programs. With Proposition 209 prohibiting public education institutions from granting preferential treatment to any individuals, it is critical that engineering colleges promote a program of inclusive diversity.

Even though there is recognition for the value of culturally-based engineering organizations, perhaps the greater benefit is gained by those who seek to develop an appreciation for cultures outside their own. Non-URM students should be encouraged to join AISES, MAES, NSBE, and SHPE, as male students should join SWE; all of these student chapters provide multiple opportunities for student engagement that are less associated with race/ethnicity and more related to career skills enhancement (e.g., industry speakers, internships, academic skills workshops, etc.). With well over 50% of Latino/Hispanic students avoiding these cultural 'comfort zones', engineering programs must accept the changing landscape of university life and recognize that millennial students are increasingly more comfortable in an environment which supports inclusive diversity. The results of this study establish engineering students' reticence about participating in racially/ethnically homogenous groups and corroborate the importance of offering a model of inclusive diversity within the engineering program.

A briefer analysis of results showed an interesting parallel between Latino/Hispanic, Asian, and Caucasian engineering students' responses. These unique responses involved Question 5, where Latino/Hispanic students were much more likely to indicate that they wanted to secure their family's financial status, whereas Asian and Caucasian students indicated that their family would benefit from their success, with family status being a secondary reason for why students were pursuing an engineering career. Noticeably, the intersection between culture, heritage, and community is highly expressed in Latino/Hispanic and Asian students' responses in Questions 1, 2, 8, and 9 but not in Caucasian students. Latino/Hispanic and Asian students show similarity in Questions 3 and 4, with responses relating family reputation to concerns about prestige from success and shame from engineering career failure. Since Asian engineering students do not generally exhibit the general at-risk behaviors, typically seen in Latino/Hispanic engineering students, these data results are interesting and must be further explored. Since the focus of this study was motivated by an interest to improve Latino/Hispanic engineering students' academic performance in an engineering program, the author plans to conduct a future study exploring the analogous perspectives of Latino/Hispanic and Asian engineering students to determine how the family and community impact a commitment to engineering program success.

Many theories and literature on the psychology of human behavior were visited to understand reasons for student success and failure. Along with the contributions made by Holland's theory of career choice [12] and subsequent research in career intervention, the theory of social congruency [2, 7, 22-27] was applicable within this study's context and provided a rational explanation for Latino/Hispanic engineering students' continued academic struggle in the engineering program. In this specific context, if Latino/Hispanic engineering students are able to believe assuredly that what they are learning in their engineering classrooms can translate into ways in which they are able to serve their own community, it is possible that their academic performance will markedly improve – even when they might be the lone URM student in their engineering program. With this line of thought, the practice of clustering students by race/ethnicity becomes obsolete, void of meaning and should be discarded.

When the academic experiences of students connect to more meaningful corollaries of students' personal and lived experiences, the ability to create effective engineering curricula is possible. This study supports the need to address students' community as being a purposeful and practical element of their educational experience. Creating project-based learning curricula that connect students to their own community might just be the panacea for improving not only Latino/Hispanic engineering students' academic performance but the academic talent of all engineering students, regardless of ethnic/racial background.

Phase 3 – Next Steps

The intent of this study was to gain a better understanding of Latino/Hispanic students' valuation of community in order to help improve their academic experience in an engineering program. Based on the results of this study, the CSULB College of Engineering is currently piloting a supplemental activity in two sections of ENGR101 in the Spring 2011 semester. Originally, the ENGR101 term project involved an information-literacy type activity; that activity has now been revised to include a project-based learning component. Working in groups of four or five, arranged on discipline, students were asked to select a topical article from the ASEE PRISM magazine and extend this topic beyond a written paper and presentation. Students were asked to select a topic that relates to their area of interest and propose a community-based project. Students are not required to carry out any community-based project but only to propose one. These proposed projects will seed a database of project assignments that will be reviewed by ENGR101 instructors; instructors will select a few low-cost projects that can be performed within the span of one semester. The CSULB chapter of "Engineers Without Borders" will be asked to assist with this project-based community-engagement learning endeavor.

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Appendix

Family and Communal Obligations (nine-item survey)

1. Even though I am busy with school, I find time to participate in my family's cultural-heritage traditions and events. *Culture and Heritage*
   - o Always
   - o Sometimes
   - o Never
   - o My family does not celebrate cultural-heritage traditions and events.

2. It is important for me to maintain or develop the practices of my cultural/heritage (even if it means sacrificing some school time). *Culture and Heritage*
   - o Always
   - o Sometimes
   - o Never
   - o I do not have any cultural/heritage activities or events.

3. My family is only one reason for my motivation to succeed. *Family Obligation*
   - o Yes - Absolutely!
   - o Not really
   - o I do not care what my family thinks
   - o My family is only one reason for my motivation to succeed

4. Succeeding occupationally in engineering is a way to make my family proud (it reflects on my family's reputation). *Family Pride and Shame*
   - o Yes - Absolutely!
   - o Not really
   - o My family will be proud of me even if I fail.
   - o I do not care what my family thinks.

5. Failing academically brings shame to my family. *Family Pride and Shame*
   - o Yes - Absolutely!
   - o My family will benefit from my success.
   - o I am undecided about how my family fits into my future career success.
   - o My success will be for my sole benefit.

6. I feel obligated to follow my parents' ideas about career choice. I chose engineering because my parents want me to be an engineer. *Family Influence/Pressures on School*
   - o Yes
   - o Yes - but I am having second thoughts.
   - o My parents did not heavily influence my career choice.
   - o My career choice was my own.

7. Which topics would make ENGR101 most interesting to me? *Importance of Community*
   - o More emphasis on engineering innovation (e.g., devices/products, etc.).

- More emphasis on engineering research (i.e., heavy focus on theory).
- Community-based projects (serving my own racial/ethnic community).
- Community-based projects (serving any racial/ethnic community).

8. Negotiating the demands of an engineering program with communal obligations is important to some students. *Importance of Community*
   - Very Important
   - Important
   - Somewhat Important
   - Somewhat Important
     Not Applicable" (I do not have any communal obligations)

9. It is important for me to maintain my cultural identity, and this is why I am a member of (or will join) a culturally-based engineering student organization (e.g., AISES, MAES, NSBE, SHPE). *My Community is Who I Am*
   - Yes - that statement is true, and I want to promote my culture.
   - Yes - I am part of a culturally-based engineering student organization but only for socialization purposes (not culture).
   - Yes - I am part of a culturally-based engineering student organization but only for exploration purposes (I am not of that culture).
   - No - I am not interested in joining culturally-based engineering student organizations.
   - No - I do not believe in culturally-based engineering student organizations (I think only major-based student organizations are acceptable).

Biographical Information

Lily Gossage is the Director of Engineering Recruitment & Retention for the College of Engineering at California State University, Long Beach. She oversees all activities regarding admission inquiry for engineering undergraduate and graduate students. She manages the engineering first-year experience community, mandatory advising, freshmen course coordination, and assessment of student success and retention. She leads the women-in-engineering initiative and fundraises for the women-in-engineering outreach programs. She is an active member of WEPAN (Women Engineers ProActive Network), a national association of women-in-engineering advocates and educators and currently chairs the WEPAN Diversity Advancement Committee. She is also a member of NAMEPA (National Association of Multicultural Engineering Program Advocates, Inc). Her most recent publication involved a four-year correlation study evaluating the impact of early engineering outreach for young women, and her most recent presentation involved promoting the climate study as a way to inculcate institutional diversity. Her interests include studying short-term outcomes of pre-engineering intervention on academic achievement and future performance in the college years.

Projects Integrating Sustainability and STEM Outreach

Shoba Krishnan, Ruth Davis, Marco Bravo, and Melissa Gilbert
Santa Clara University

Abstract

This paper reports on a program that provides senior engineering majors with the opportunity to complete a community-based project addressing an educational need, not only allowing undergraduates to apply engineering knowledge, but also expanding STEM experiential learning opportunities for diverse middle school youth.

The senior projects involve designing sustainable engineering systems to solve the energy needs of an outdoor science camp in the local community. The undergraduate engineering students also collaborate with educators to develop age-appropriate STEM learning. In this paper we will describe the projects and the STEM activities we developed. We will discuss how we established a long-term partnership with a science camp and the interdisciplinary nature of the partnership.

We also show through data collected from engineering student interviews and surveys how this partnership helps the engineering students understand and gather requirements for a real-world project and at the same time inspire the younger generation visiting the camp to use science and technology for the common good. Results from a survey administered to middle school students illustrates they knew more about the engineering design process and were more likely to consider a career in science or engineering after their experience with the sustainability unit. Overall, positive attitudes, knowledge, and efficacy toward STEM were found.

Introduction

Today's industries need engineering graduates who have a broad outlook on the world. This has prompted many institutions to give greater importance to skills such as interdisciplinary teamwork, effective oral and written communication and social consciousness. In light of these criteria, many institutions are consistently striving to enhance their educational program in order to prepare students to be competent ethical professionals and effective global citizens. National statistics show that 5 of the top 30 fastest growing occupations are in engineering and computing[4]. Yet the United States continues to matriculate science and engineering graduates at rates well below global averages. Students receiving their undergraduate degrees in the natural sciences or engineering from United States undergraduate institutions represent 16 percent of total enrollment of those institutions. This contrasts with 47 percent in China, 38 percent in South Korea, and 27 percent in France[3]. The National Academies' report "Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5" paints a bleak picture of America's competitive position in the world[6]. The principal focus of the original "Gathering Storm" report in 2005 was on STEM fields, both because of their critical importance in creating jobs and because of the failure of the American education system in these areas[5]. The "revised" report states that the situation has worsened. This has prompted many engineering programs to develop and use innovative strategies that integrate active learning with relevant engineering applications.

At Santa Clara University, our core curriculum includes requirements in "Experiential Learning for Social Justice" and "Civic Engagement," as well as other more traditional areas. Experiential learning through involvement in community-based projects integrates service with academic education. Students apply classroom knowledge to community problems, thus enhancing learning while providing needed services to society. Research has shown that experiential learning reinforces classroom knowledge and helps in student retention.

Our own work reported by Davis[1], states that showing the social relevance of engineering by engaging the students with the community in an effort to define and implement projects that meet real needs seemed to have a positive effect on the involvement of women and minority students. Over the course of three years of community-based projects, it was found that 75% of the students who elected to participate were women, and 50% were members of an ethnic minority underrepresented in engineering. This was a disproportionately large percentage of each group, as the engineering enrollments at the time were only 23% female and 15% underrepresented minorities.

Our program ensures our students the opportunity to participate in interdisciplinary projects for the benefit of a local community, strengthening their commitment to engineering. This focus on real-world projects helps our graduates meet the industry's need for more practical experience. In addition, the decline in interest in engineering among K-12 students prompted us to ensure that our program includes the development of a STEM outreach component.

Our goals in designing this program were to:

- Develop a strong curriculum that engages students in taking responsibility for the definition and integration of their educational experience;
- Educate the community to the value of engineering as a discipline for designing a better world, resulting in a wider pool of students with the knowledge of engineering as a viable option for study; and
- Improve the diversity of the engineering workforce through both retention of underrepresented undergraduates participating in the program and recruitment of minority middle school students to pursue engineering.

Projects for Walden West Science Center

This program supports senior design projects that develop engineering systems to meet the needs of Walden West, a local outdoor school and science camp located in Saratoga, California (http://www.sccoe.k12.ca.us/waldenwest). "The mission of the Walden West Science Center is to immerse students in the world of science and inspire environmental stewardship". Walden West requires sustainable and eco-friendly systems to meet the operational needs of the school. They also desire an environmental education component to accompany the physical systems to enhance their curriculum.

All projects have the same fundamental requirements that are challenging to meet for the undergraduate students. The designs have to be cost effective with minimal maintenance and must be completed in one academic year. Environmental impact must be considered in all decisions during the design process as the camp focuses on teaching about sustainability and its effect on the environment. Each year, new projects have been added to support our ongoing relationship with Walden West. These projects offer the opportunity for engineering students to build systems related to sustainability and reach a new cohort of middle school students with an expanded offering of curriculum. Partnerships with the department of Education at our institution assured the pedagogical considerations in these projects for middle school students were sound.

We started “Sunflower” in the 2008-2009 academic year with a team of three female senior electrical engineering students. The project involved developing a sustainable, solar-powered water pumping system to meet the irrigation needs of Walden West using reclaimed storm drain water and solar energy. The physical system components of the piping, pump, controls, and solar array are shown in Figure 1. Many aspects of the engineering design were truly interdisciplinary as electrical engineers do not have formal instruction on hydraulics. The team had to work with mechanical engineers to research pipe characteristics and do fundamental calculations to find the friction head and hydraulic power requirement.

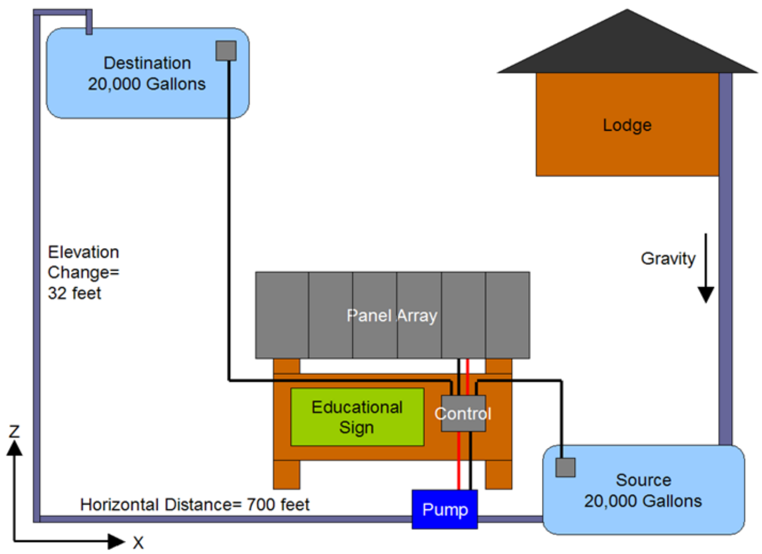


Figure 12: System Diagram of “Sunflower” project

The next year another team of three female senior engineering students (two mechanical and one electrical) designed and built an “Energy Bike,” demonstrating how students can create their own energy and providing a foundation for the study and development of additional alternative energy ideas. This Energy Bike, which the team built by refurbishing an old exercise bike as shown in Figure 2, would allow the campers to actively pedal the bike, which would in turn power an appliance or charge a battery pack. This project had the added challenges of having higher safety standards as it had to be efficiently operated by middle school students. The engineering students designed an interface that accurately shows the amount of power produced in correlation to how fast the person is pedaling so that the campers could relate effort put in to energy consumed.

Figure 2: Mechanical system of Energy Bike

In the current academic year, the project "Blades of Power" investigates another source of sustainable energy: the wind. The senior team of three female students (one electrical and two mechanical engineers) is developing a wind power system using two small scale wind turbines specified to function for the wind patterns of the area. The two turbines will have different orientations; one will be a horizontal axis turbine (HAWT) and the other will be a vertical axis turbine (VAWT) as shown in Figure 3. Additional challenges for this project are to guarantee no significant environmental impact on bird migration paths through the camp and to ensure the municipality checks that all safety factors are within compliance. The students will also build an interactive tool to add to the curriculum for Walden West.

Figure 3: Wind Turbine Systems to be installed at Walden West

A second project this year, “Make It Rain” is extending the “Sunflower” project to build a drip system to irrigate the garden by using excess rainwater. This team consists of three mechanical engineering students (all male). The system, shown in Figure 4, collects solar energy during the day to power a pump that moves water from the existing storage tank to pressure tanks. Put simply, the energy from the sun is stored as pressure or potential energy in the pressure tanks from which the drip irrigation is operated. This system will enhance the aesthetics of the camp in a sustainable and economical manner and will display sustainable technology in an area visible to the campers.

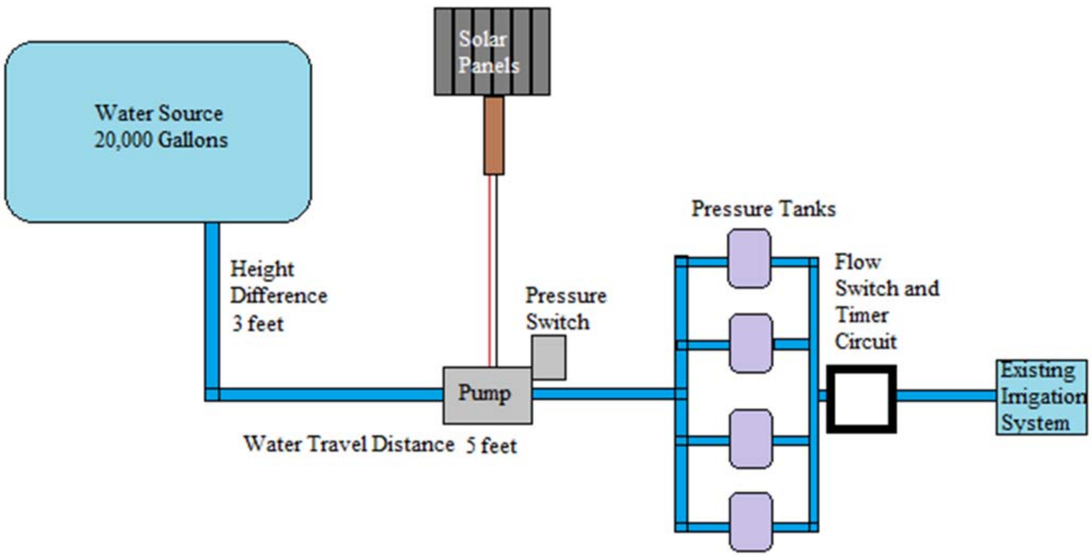


Figure 4: Block Diagram of “Make It Rain.

All the projects implemented at Walden West not only satisfy an engineering need but also tie into their curriculum. This community partnership has always been symbiotic with Santa Clara University students gaining design experience and the Walden West camp getting infrastructure built. Now this strong ongoing relationship is becoming self-sustaining with students brainstorming ways of integration for more efficient use. For example, during the design phase, the two teams of this academic year are planning to build an energy storage system that combines the solar power generated from “Make it Rain” with the wind energy harnessed from “Blades of Power”.

STEM Outreach Component of the Projects

Walden West’s camp program is operated on the premise that students learn best through involvement in hands-on educational activities. “The mission of the Walden West School Foundation is to inspire every student in Santa Clara County to learn about and comprehend the important role that science plays in their daily lives and in the lives of those around them.” (http://www.waldenwestfoundation.org/default.asp).

Therefore, each project develops a hands-on educational model and lesson plan to accompany the designed system. The lesson plans developed present a good introduction to the concepts of engineering for students who have not been exposed before. The projects focus on renewable energy systems, demonstrating the importance of sustainability and engineering to fifth and sixth grade students in Santa Clara County. Approximately 11,000 students visit the camp each year from the Bay Area. Moreover, Walden West works with a wide range of schools from different socioeconomic backgrounds; therefore students of all economic strata gain similar experience. Following are the age appropriate STEM activities and lesson plans that have been developed through outreach.

The Sunflower team developed a lesson plan for Walden West and one for a middle school classroom. These two plans vary slightly in their activities respective to their context. Both lesson plans promote learning about environmental and sustainability issues while addressing the following fourth, fifth, and sixth grade California science and math standards. We addressed a 4^{th} grade standard as Walden West is visited by students as young as fourth graders.

CA Science Content Standards, Grade 4 - Physical Sciences

1 g. Students know electrical energy can be converted into heat, light, and motion.

CA Science Content Standards, Grade 6 - Focus on Earth Science, Resources

6 b. Students know different natural energy and material resources and know how to classify them as renewable or nonrenewable.

CA Mathematics Content Standards, Grade 5 - Mathematical Reasoning

1.0 Students make decisions about how to approach problems

2.0 Students use strategies, skills, and concepts in finding solutions

3.0 Students move beyond a particular problem by generalizing to other situations.

Students at Walden West will learn about the Sunflower water pump system through three sub lessons that cover solar power, conserving resources, and doing work. Students experience the power of solar energy hands-on, by experimenting and taking measurements with a miniature solar powered fan and multi-meter. Another activity focuses on identifying actions they can take to conserve resources. Finally, students get a physical feel for how much work the Sunflower system does by carrying water between two stations and performing some simple math calculations. The classroom version of the lesson plan was piloted in a sixth grade science class at a private K-8 school in the South Bay Area, California. One of the activities is a Solar Cell Simulation that helps students understand how solar panels work. A sample of the post assessment of classroom learning done after this activity is shown in Figure 5.

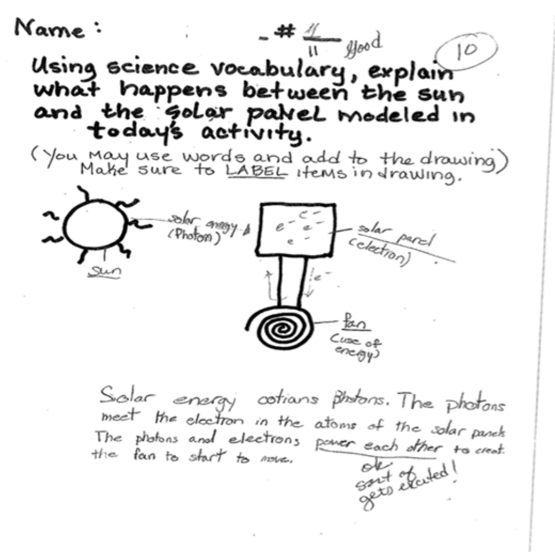


Figure 5: Sample of Student Assessment from "Sunflower" lesson plan

With the Energy Bike, students create their own energy and observe how much power they can generate by supplying different outputs. The senior team wanted the students to experience something that would help them understand the fundamental concepts of energy and demonstrate how mechanical energy can be transferred into electrical energy, and to engage them in a physical sense to see how they could save electricity at home. The bike was hooked up to a light box, shown in Figure 6, to demonstrate to the students how their peddling affected the ability to light both a traditional incandescent light bulb and a fluorescent energy-saving bulb.

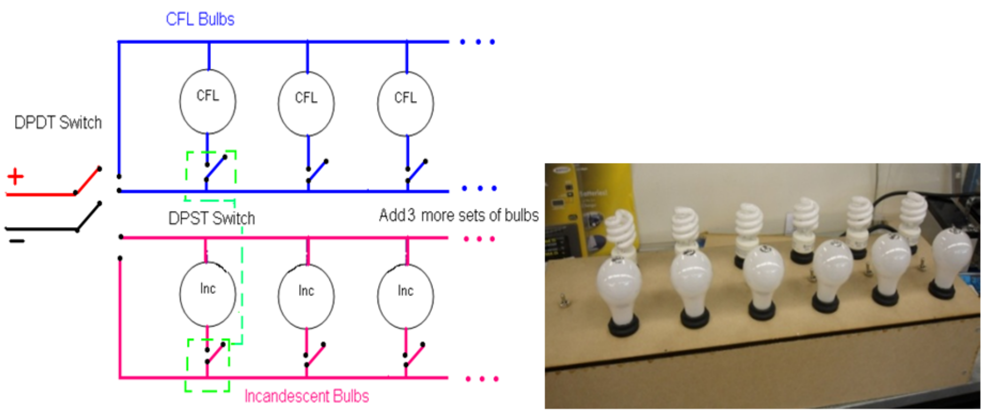


Figure 6: Lightbox in Energy Bike project

The Blades of Power project will have an interface to the turbine systems, which will be the main educational component and will consist of several different aspects, including the local area anemometer, energy generated from each of the three different turbines, and an educational chart. Figure 7 shows the initial design as this project is ongoing. The wind turbines will allow the children to visually see how much energy is being produced based on the amount of wind and how fast the blades are spinning. The campers will be able to evaluate different scenarios and observe how different elements can impact the power generated. A display board will be added to demonstrate the amount of energy used to power everyday household appliances to create awareness for the kids.

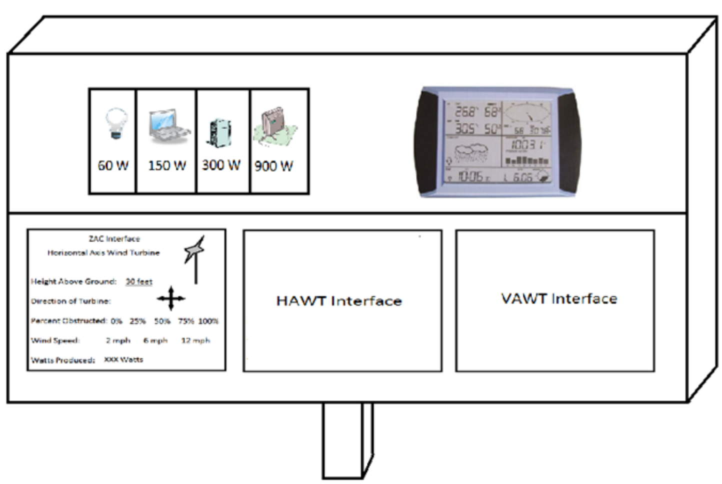


Figure 7: Educational Display for "Blades of power"

Measures Used to Assess Efficacy of Program

To assess the efficacy of the program, we collected data and conducted analyses of the experiences of the engineering students as well as those of the middle school students visiting Walden West. This was accomplished using:

- Interviews of engineering students to assess efficacy of the project in achieving the learning outcomes for the engineers, and to identify possible improvements;
- Interviews of Masters students in education who are also classroom teachers;
- Surveys of all senior engineering undergraduates in order to compare learning outcomes for students who work on community projects with those who work on traditional capstone projects;
- Pre- and post-lesson surveys to gauge middle school students' comfort level with science, math, and engineering, and understanding of engineers and what they do; and
- Teacher-generated assessments in science class and math class to measure the student learning from the lesson plans developed.

Learning Outcomes for Engineering Students

These projects increased the expertise of the students as active engineering professionals, taking on community projects and delivering a quality product that met customer expectations. This section highlights efficacy of the project in achieving the above goals, and includes relevant comments taken from interviews with students on the most effective aspects of their experience.

Through the Sunflower project – designing and building the physical system, developing the educational component, as well as working on an interdisciplinary team – the students accomplished several goals that had motivated them to choose this project. Below are responses from the interviews of the three engineering students conducted independently by a neutral party after completion of the project

[The design goal of the project was] to build a physical system that utilizes solar water pumping for irrigation. [We] also wanted to teach students about solar energy.

They learned the process of design and development and were able to draw on their engineering classes and apply their theoretical knowledge to practical problems. While working in the community, students gained practical hands-on experiences that they would not have ordinarily received in the classroom or traditional lab setting.

[We learned] how to work on a project from start to finish, see it through and make sure the deliverable exceeded the standards.

The project provided opportunities for the students to work with an external community client on the development of a solution to solve a problem or fulfill a need. The students learned to work with a "customer" and develop project goals and specifications to develop a cost effective solution with minimal maintenance that could be sustained at the site.

We worked with Walden West Outdoor School. They were a great customer/community partner to work with. [We developed a] sustainable, economic, and educational system.

[The most effective aspect was] the fact that we had to present [the system] and actually complete the project so the customer would be satisfied with the result.

They learned the skills of project and time management so that the project was completed to specifications in one academic year.

[We learned] group projects take a lot of patience and organization. It is important to have a leader to motivate the group.

[We learned about] working with a team and meeting all deadlines.

The two completed projects (Sunflower and Energy Bike) were awarded the distinction of "Best Community-based Project" at the senior design conference in their respective years. Below is a comment from a student on the Energy Bike team.

"Obviously we wanted to do the best job possible, but the giving back to the community aspect was the key part of the process for us—that was the reward for us at the end of the day,"

One observation we made was that of the 4 projects and 12 students, 3 have been teams of women giving us a 75% participation rate of underrepresented participants. This is consistent with the experience reported in reference 5 based on projects completed in 2001 – 2003. We believe the involvement of underrepresented students is important, both because it indicates that these students may be drawn to and persist in engineering due to these experiences and because they provide role models that allow students from underrepresented groups see engineering as a possible future for themselves. We are led to conclude that community-based projects may be a powerful tool in increasing diversity in engineering.

Interdisciplinary Partnership

The pilot project "Sunflower" was successful in creating a partnership between SCU Department of Education and the School of Engineering faculty and students to foster dialogue and collaboration, focusing on STEM educational outreach activities. The SCU engineering seniors worked closely with their engineering faculty advisors on engineering aspects of the projects. For the educational component, they worked closely with graduate students in education to develop lesson plans and understand the California Math and Science standards. Separate lesson plans were developed for implementation at Walden West utilizing the engineering installation and for implementation in middle school math and science classrooms, utilizing a simulation of the system using a solar-powered fan. The middle school teachers helped develop and executed the lesson plans and hands-on activity in their classrooms. They also conducted pre- and post surveys to help evaluate the project goals.

Both the engineering undergraduate students and the education graduate students (who were the classroom teachers) commented on the value of the interdisciplinary collaboration. One engineering student recalled feedback she received from the classroom teacher when a lesson plan was piloted:

Another thing we would change in our lesson plan before performing it again resulted from basic feedback from the teacher as far as the classroom management goes. ... I know at Walden West, it is important to do English Language Learner friendly lesson plans – just having more visual aids than the words written in the lesson plan.

The collaboration also benefited the classroom teachers/education master's students.

It [The lesson] was very engaging; they [the engineering students] covered standards that I don't get to cover, so that was really nice, that's what I really liked about it.

My experience was terrific. I loved it; it was fun to collaborate with the engineering students. It's nice to be able to deliver something different. And, that's instruction the kids wouldn't have gotten.

One education master's student commented on the way that this interdisciplinary project inspired students' interest in STEM fields:

The kits and the way that they tie together the idea that the sun [is] a resource and [is] actually doing useful work. And, the fact that the kids have hands-on and taking these things outside, are terrific. I've used them in a couple of classes and it really excited students' curiosity, [student comment] "Wow, I get to put something together and make it work." [It] was really good. It ignited their curiosity about the topics.

The engineering students also worked closely with the camp counselors and instructors at Walden West. For example an excerpt from the "Sunflower" thesis explains how this collaboration worked.

"The original idea was to design a miniature version of the large-scale physical system so that the students could witness the water pumping and play with the system. We considered having a solar panel mounted on a pole that was short enough so that the students could tilt the panel and create artificial shade with their hands. In order to get a better idea of what would be appropriate for the learning atmosphere at Walden West, each of us individually shadowed a class for an afternoon. The field instructors recommended that we create an educational activity where small groups of children would perform a task because 20 students cannot experiment with one solar panel at the same time. From this feedback, we modified our activity to include miniature solar powered fans where groups of three students can all have a role in the experiment simultaneously."

About working with Walden West, one of the "Energy Bike" seniors said, "*I knew it was going to be rewarding, but not to this extent. It blew me away to see these kids light up—both literally and figuratively."*

One of our main goals was to have engineering undergraduates as teachers, role models, and mentors. Our findings were that the engineering students needed guidance to implement age-appropriate lesson plans, classroom management skills and understanding of what content standards have to be met. Collaborating with educators in formal classroom settings and at the Walden West camp is essential for success of the STEM intervention. Another important step in this intervention is teacher training on the technological aspects of the systems and the engineering fundamentals that go into it. In our projects the engineering students did demonstrations of their systems and also were present for the first implementation of their lesson plans after which the instructors gathered enough knowhow to continue on their own. So in this way we were successful in having our undergraduates be teachers, role models, and mentors, albeit for a short while.

Middle School Student outcomes with regard to STEM learning and STEM dispositions

This portion presents the measures used and findings on the impact of the Sunflower project on middle school student learning and attitudes toward STEM learning. Measures of student efficacy, knowledge and attitudes toward STEM learning were used to gauge the effectiveness of the intervention. The following analysis summarizes the responses for the twenty-five middle school students in the sample.

The research team utilized data from two sources to test the efficacy of the intervention—a STEM attitudinal survey and a STEM assessment.

STEM Assessment. The 6th grade classroom teacher generated an assessment to gauge student learning from the lesson plans delivered. The following prompt was provided to students:

"Using science vocabulary, explain what happens between the sun and the solar panel modeled in today's activity"

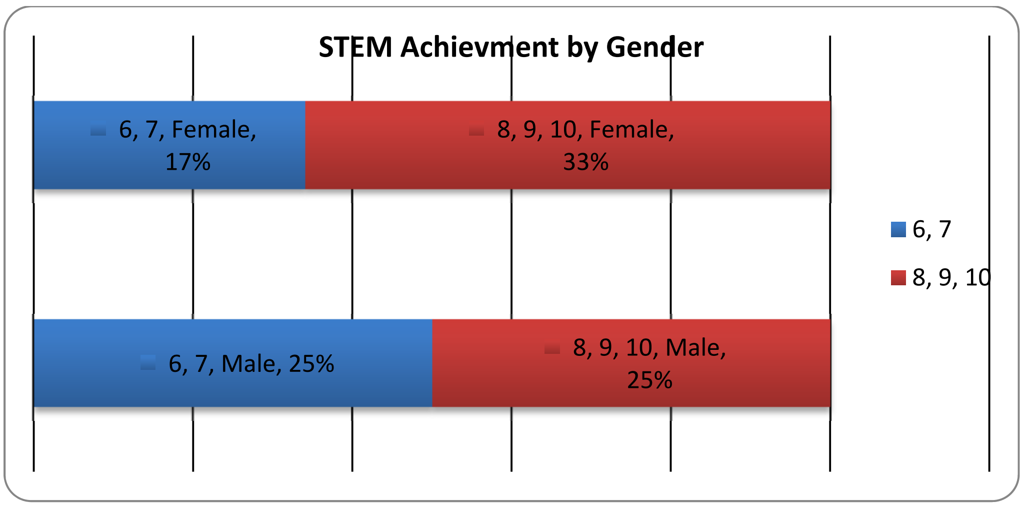
An image of the sun with a solar panel and fan are provided and students are asked to use words and add to the drawing, making sure to label items in the drawing. Students receive a score from one to ten based on their scientific accuracy and use of science terminology in their response. The assessment was only administered at the conclusion of the delivery of the lessons and was scored by the teacher on the dimensions mentioned above.

The student example shown earlier in Figure 5 provides an exemplar of the type of work students produced on this assessment. The sample demonstrates how the student uses several of the science vocabulary words (e.g., solar energy, photon, atoms) correctly and clearly illustrates the relationship between the various components involved in the solar panel model. The conceptual understanding is evident with both the student use of terms appropriately and correctly illustrating the relationship between the various components involved in the activity.

The assessment was scored by the classroom teacher and was given a score out of a ten-point possible total. Given that a pre-test was not administered, gain scores are not possible, but an analysis is possible of achievement by demographic variable. In Figure 8 we provide the scores for the students in the class disaggregated by gender and whether they scored a 6-7 or 8-

10. A score of 8-10 meant a grade of B or better where a score of 6 or 7 meant a grade of B- or lower. Girls in the classroom scored better than boys on this assessment. Of those students that scored an 8, 9 or 10, (58% of the class) 57% of them were girls while 43% were boys. Boys were overrepresented in the lower scores on this assessment, making up 60% of students in this lower range of scores, while only 40% of girls scored this low on the end-of-lesson assessment.

Our interest in how students from different ethnic groups scored on this assessment led us to examine the assessment scores by ethnic group. This student assessment was a teacher created instrument, used to inform her practice. The survey measure was not validated due to small number of participants participating in the survey. Figure 8 illustrates the breakdown by ethnic group. While there was an overrepresentation of White students in the sample, we are able to see that students from different ethnic groups scored equally well as the White students in the class on the STEM assessment. Future work will ensure equitable representation of various ethnic groups to investigate what types of supports and scaffolds we can implement to support the needs of students from diverse ethnic backgrounds.



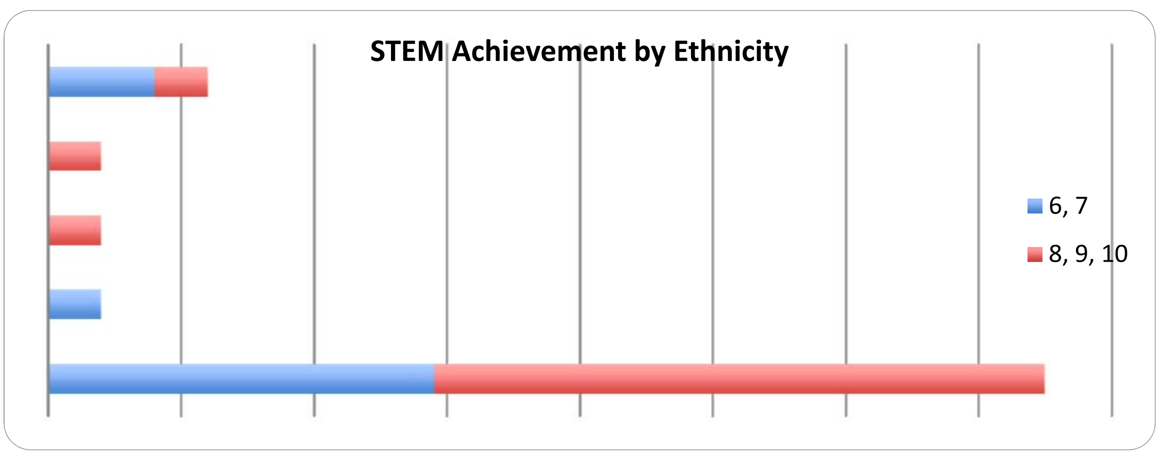


Figure 8: Charts showing STEM achievement demographics for classroom assessment

STEM Attitudinal Survey. The STEM survey consisted of ten Likert-Scale items that asked students to rate their experiences with STEM by selecting from "Very True, Mostly True, Somewhat True, A Little True and Not True". Items were organized around three constructs:

1. Self-Efficacy in STEM Learning (e.g., I am good at using technology)
2. Knowledge of STEM ideas (e.g., I know about the engineering design process)
3. Attitudes toward STEM Learning (It is fun to learn about science, technology and engineering)

The survey was administered before and after the implementation of the intervention. The classroom teacher administered the survey and coded each student name before submitting the surveys to the research team.

At the onset of the intervention, student sense of self-efficacy in doing STEM was stronger than their knowledge about or attitudes toward STEM dispositions as seen in Table 1. At post survey, statistically significant differences were found. Students displayed stronger efficacy, knowledge and attitudes toward STEM learning, with strongest gains in knowledge about the nature of STEM work. Students felt they knew more about the engineering design process as a result of the intervention and were more likely to consider a career in science or engineering. These positive attitudes toward these aspects of STEM fields address the issue others have found for middle school students, namely that low performance in science and math is more likely due to attitude than aptitude[2].

Table 1. Middle School Student STEM Survey (n=25)

	Pre	*Post*	*Gain Score*	*Significance*
Self-Efficacy in STEM Learning	3.7	4.0	0.3	*
Knowledge of STEM Ideas	3.1	4.1	1.0	***
Attitudes toward STEM Learning	3.1	3.6	0.5	**

Note: *$p < .05$; **$p < .01$; ***$p < .001$

Overall, positive attitudes, knowledge and efficacy toward STEM were found, with boys posting stronger growth in the attitudes and efficacy domains. This suggests a need to refine the intervention to be more responsive to the needs of girls. These modifications can include increasing the visibility of women in STEM fields and discussing why this gender gap might exist. The assessment of the classroom lesson for middle school students has only been completed for the Sunflower Project, as it was the first completed and we have had a year to offer the educational units developed for this project.

The Energy Bike team also conducted a pre-assessment of the students' knowledge on power, renewable energy, and science in general before demonstrating the Energy Bike and executing the lesson plan activities at Walden West. At first the kids were a little subdued—maybe intimidated—but once the team demonstrated how the energy from peddling the bike made smoothies, they wanted to know more. When the kids saw firsthand they could light up so many more fluorescents so much easier, the team noted a marked shift in their reactions. One of the seniors reported: *"So you can 'feel' that the fluorescents take less energy, and seeing the energy bike in action this way turned an abstract into a physical feeling that they could grasp". "It was significant," "They saw that science was cool and this is what you could be doing if you studied science in school."*

We plan to continue implementing similar surveys and assessments at Walden West with visiting classroom teachers doing in-class assessment to gauge student learning. Establishing the method of data collection and analysis for these efficacy measures is ongoing.

Conclusion

Our initial findings suggest that these projects enhance our engineering undergraduates' readiness and preparation for future employment by developing stronger communications, team-building, and project skills. Results indicate that these projects also help to increase their expertise and attitudes as active, civically-engaged engineering professionals, able and willing to take on community projects and deliver a quality product meeting customer expectations.
One goal of these projects was to increase middle school students' knowledge, skills and dispositions toward STEM learning. Embedding math and science learning in solving engineering "problems" had a positive effect on all students, as gauged by the *STEM survey* and *STEM assessment*. Yet, disaggregating the data uncovered a need for a more responsive approach to this work considering the needs of diverse learners. Particularly, while girls made similar gains to boys, in fact, showing a higher level of knowledge achievement, in order to close the gap with respect to efficacy in doing the work of STEM, stronger efforts should be made to make women in STEM careers more visible and hence possibly create stronger efficacy outcomes for girls. Similarly, with students from culturally and linguistically diverse backgrounds representing the fastest growing sector of the school-age population, how best to be responsive to these students' STEM needs has gained considerable importance. Hence, future implementation of this intervention will consider school contexts that are more representative of public schools in California to better gauge types of modification to the intervention that might be especially efficacious to this academically vulnerable student population. Nonetheless, findings from these projects show great promise and results that can certainly serve as a guidepost for future implementation of this important work.

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Work in Progress: Pathways to Science, Technology, Engineering, and Mathematics Opportunities via Academic Success and Internships

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Abstract

The fusion of a state funded student success program and a supporting NSF grant provide model pathways to Science, Technology, Engineering and Mathematics (STEM) opportunities that students from San Diego community colleges and university take toward achieving STEM industry positions or graduate school. The STEM Partnership of San Diego (SPSD) which, as a work in progress in its fourth of five years, is a student success initiative built on best practices of the Mathematics, Engineering, and Science Achievement (MESA) Program and grant funds from the National Science Foundation (NSF). The SPSD provides essential academic and career development services to students majoring in STEM fields. Services include internships and/or undergraduate research experiences for diverse students. More than 600 STEM students are served annually at the community college and university level. The best practices of MESA focus on student groups that historically had low levels of attainment; SPSD enhances academic support, provides service to additional students, and consolidates student/industry involvement thus providing the students with career and leadership development skills. Students in these programs outperform their peers and standout in job/internship interviews due to their tangible excellence.

The SPSD student support is based on ‘standards’ identified by industry representatives as critical for success. As a result of completing activities that are in line with these standards, students gain career development experience, workforce preparedness, and academic success. Upon achieving the standards, successful SPSD students improve their potential opportunities in STEM careers, including the option of attending graduate school to pursue an advanced degree. Evaluation of the standards, implemented by means of student activities, proves that they are effective.

Introduction

San Diego has an extensive technical and scientific base of aerospace, biotechnology, communications, and computer-related companies, as well as research institutes, universities, and medical centers. San Diego also has a diverse ethnic and economic population. Currently there are individual programs in San Diego, derived from the nationally-recognized Mathematics, Engineering, Science Achievement (MESA) Program, that assist underrepresented students to earn degrees in Science, Technology, Engineering and Mathematics (STEM) fields. The MESA mission is to enable educationally disadvantaged students to prepare for and graduate from a four-year college or university with a math-based degree while developing academic and leadership skills, increasing educational performance, and gaining confidence in their ability to compete professionally. The San Diego MESA programs rely on the support of an active Industry Advisory Board (IAB) for program and student development. Established in California in 1970, there are currently 68 MESA

Programs statewide serving K-12, community college and university students, and the MESA model has been adopted in thirteen other states. Furthermore, MESA has been named one of the most innovative public programs in the nation by Innovations in American Government, a project of the Kennedy School of Government at Harvard University, and the Ford Foundation. Among countless other awards, MESA has also earned the Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring. Additionally, MESA was also featured in a half-hour national PBS documentary *The Innovators: Designing the Future*, as one of the solutions to developing the next generation of innovative engineers and scientists.

The National Science Foundation (NSF) selected San Diego MESA as a recipient of a $1.9 million dollar **S**TEM **T**alent **E**xpansion **P**rogram (STEP) grant to support the STEP Partnership of San Diego (SPSD). Awarded to the college members of the San Diego MESA Alliance, comprised of MESA Programs at San Diego City College (SDCC), San Diego State University (SDSU), and Southwestern College (SWC), this grant was one of 22 awards from a pool of 174 submitted from across the United States in 2007. This is a five year grant, currently in its fourth year, slated to end in fall 2012. As such this paper reports the efforts of work in progress.

SPSD built on MESA best practices by creating a regional partnership of educational institutions and industry (over 40 regional companies and government agencies) that forms a STEM pipeline from community college-to-university-to-STEM industry workplace, thereby developing a diverse skilled workforce for San Diego and the nation. The SPSD mission is to provide "out of classroom experiences" that help students excel academically, develop leadership skills, gain industry exposure, and network with peers and mentors, as they form their goals to stay on track for graduation in the STEM fields and are better prepared to enter the STEM workforce. All SPSD activities are based on "standards" developed with IAB input to meet industry needs for qualified engineers and scientists. In particular, the grant offers students new and exciting activities to expand their horizons and their opportunities, including:

- Industry sponsored Training Academies
- Summer Team Internships
- StrengthsQuest assessment and analysis
- Faculty Advisors
- Professional Development with industry partners
- Scholarships
- Regional STEM Competitions
- San Diego Region Joint Planning Conference

One of the most significant activities is the summer team internship in leading science and engineering firms across San Diego county providing students with opportunities to increase their knowledge and to develop skills for academic and workplace success, and ultimately to become part of the region's economic development. The SPSD activities are designed to address three important educational factors:

- Raising minority academic achievement in science and engineering
- Providing necessary guidance and financial assistance
- Providing essential support to increase persistence to graduation

Students who participate in the SPSD program are more likely to achieve a high level of success in STEM academic pursuits—academically, personally, and professionally – by completing SPSD standards. Upon graduation, SPSD students offer employers a talented, diverse pool of highly skilled STEM professionals. The goals of SPSD are:

1. Expand the participation - in multiple STEM education and career pathways - of undergraduate students from historically underrepresented populations, including Hispanics, African Americans, Native Americans, and women.
2. Improve the retention of SPSD students.
3. Increase the number of SPSD students graduating with STEM B.S. degrees.
4. Provide STEM Industry Internship opportunities to an increased number of SPSD students.
5. Promote post-graduate STEM opportunities for SPSD students.

Background

The SPSD educational partners have joined to address the underachievement in STEM fields of large numbers of low-income and educationally disadvantaged students –in particular, underrepresented minority (URM) students, who are left out of the science and technology-fueled economic growth in San Diego.

Advances in Science and Engineering (S&E) are ever more critical for the U.S. to maintain its position of leadership in STEM and keep its competitive edge in the global marketplace[5,15], yet the "new" American dilemma is ever more urgent in the 21st century, given that minorities remain seriously underrepresented in science and engineering, while they are also the most rapidly growing segment of the population[4]. As reported in a 2010 report, *Expanding Underrepresented Minority Participation: America's Science and Technology Talent at the Crossroads*[5]:

> Underrepresented minority groups comprised 28.5 percent of our national population in 2006, yet just 9.1 percent of college-educated Americans in science and engineering occupations (academic and nonacademic), suggesting the proportion of underrepresented minorities in S&E would need to triple to match their share of the overall U.S. population. (p. 2)

Furthermore, a review of bachelor's degree completion rates among "initial STEM majors" reveals that, while URM students have reached parity with their White and Asian American counterparts (from 1985 – 2009) in terms of their proportional interest in majoring in STEM disciplines at the beginning of their undergraduate studies, URM students are significantly behind White and Asian American students in completing STEM degrees within 5-years[7].

- In 2009, 34.1% of URM students and 34.3% of White and Asian American students indicated on the 2009 Freshman Survey (an annual survey administered by the Cooperative Institutional Research Program at the Higher Education Research Institute at the University of California, Los Angeles) that they planned to pursue a STEM major.
- Among 2004 freshman STEM degree aspirants, approximately 33% and 42% of White and Asian American STEM majors, respectively, completed their bachelor's degree in STEM within five years of college entry. In contrast, Latino, Black, and Native American students achieved STEM completion rates of 22.1%, 18.4%, and 18.8%, respectively.

In response to the region's need for scientists and engineers, SPSD builds on the best practices of MESA, which provide the necessary academic support and social integration that are critical for the success of underrepresented minority students[1,8,9,16]. MESA activities include peer-to-peer support, study groups, social activities, tutoring, mentoring and basic professional development activities. Grant funds from NSF provide opportunities for industry internships, research experiences and additional professional development activities[6].

The SPSD also presents a unique pipeline-partnership of educational institutions: each SPSD partner is an Hispanic Serving Institution (HSI), with 59.8%, 38% and 25.3% Hispanic enrollment for SWCC, City and SDSU, respectively. Community colleges are serving an increasingly key role in facilitating and increasing the successful transfer of underrepresented minorities in STEM to four-year institutions[2,10,11,13,14], and HSI's have a legacy of recruiting, retaining, and graduating a disproportionate number of minorities[3,12]. Also, SDSU is the fastest gainer in overall (all majors) graduation rates among all public research universities in the nation, with an increase in graduation rates of 17 percent over the past six years.

Student Participants

The SPSD partners recruit students interested in STEM majors, especially underrepresented students, including Hispanics, African Americans, Native Americans and women. Participating students must be eligible for Intermediate Algebra or above, and priority is given to economically or educationally disadvantaged students. Figure 1 provides a student profile by ethnicity. A profile of SPSD students by headcount, gender and STEM majors is provided in Table 1.

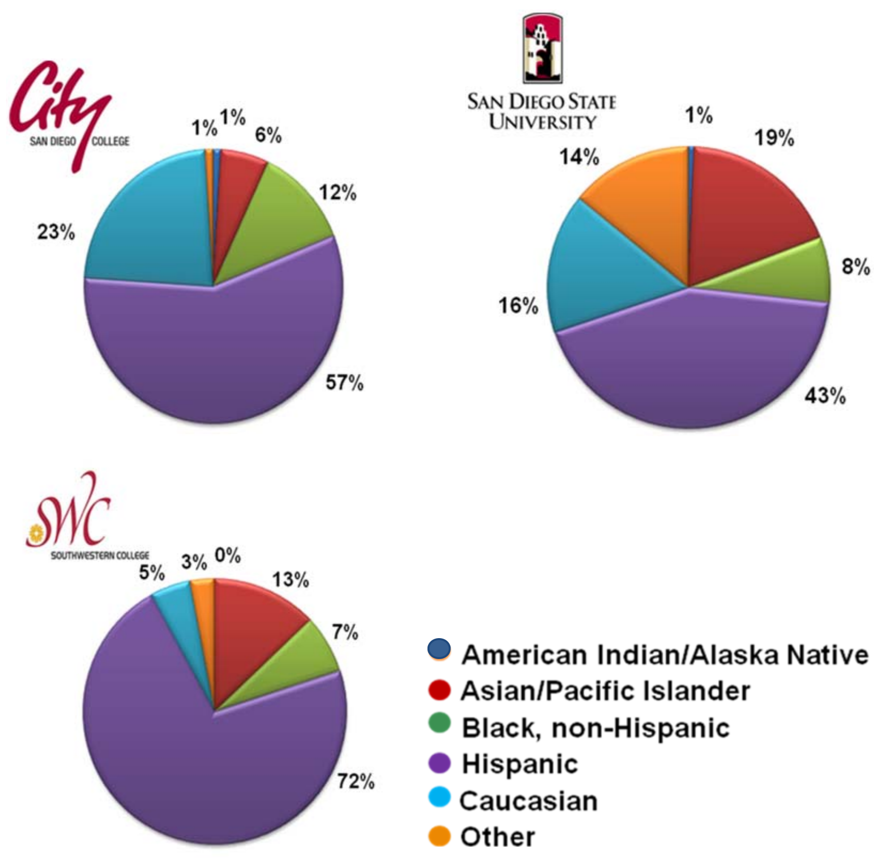

Figure 1. Ethnicity of SPSD participants at each partner institution.

Table 1. SPSD Student Profiles – Headcount, Gender and STEM Majors.

Students – Year 4	**City**	**SDSU**	**SWC**	**Total**	**Percent**
MESA	109	204	121	434	72.2%
NSF	51	88	28	167	27.8%
Total Students Served	**160**	**292**	**149**	**601**	**100.0%**
Gender					
Male	90	226	91	407	67.7%
Female	70	66	58	194	32.3%
Total Students Served	**160**	**292**	**149**	**601**	**100.0%**
Student Majors					
Science					
Biology	25	0	42	67	11.1%
Chemistry	5	16	6	27	4.5%
Nursing	9	0	5	14	2.3%
Pharmacy	0	0	1	1	0.2%
Physics	5	1	3	9	1.5%
Pre-Med	2	0	3	5	0.8%
Other Science	8	3	8	19	3.2%
Technology					
Engineering Technology	0	0	0	0	0.0%
Engineering					
Aerospace Engineering	6	32	2	40	6.6%
Architectural Engineering	3	0	2	5	0.8%
Bio Engineering	6	0	7	13	2.2%
Bio-Chem Engineering	1	0	4	5	0.8%
Chemical Engineering	2	0	0	2	0.3%
Civil Engineering	19	71	7	97	16.1%
Computer Engineering	8	20	5	33	5.5%
Construction Engineering	1	10	1	12	2.0%
Electrical Engineering	20	49	6	75	12.5%
Environmental Engineering	4	9	2	15	2.5%
Mechanical Engineering	16	58	5	79	13.1%
Structural Engineering	1	0	0	1	0.2%
Other Engineering	1	0	24	25	4.2%
Math/CS					
Computer Science	6	10	9	25	4.2%
Mathematics	12	13	7	32	5.3%
Total Students Served	**160**	**292**	**149**	**601**	100.0%

Implementation Strategies for SPSD and MESA Activities

SPSD is building a sustainable program in which partners at multiple educational segments contribute their strengths and work together over the long term. The plan is based on effective prior work at each site with underrepresented students through MESA. The key elements of SPSD are:

- A regional STEM pipeline of educational institutions that supports multiple pathways to STEM careers.
- Educational experiences and activities based on industry driven standards for comprehensive student development – academic, personal and professional.
- The use of best practices in STEM education.
- An active pool of industry partners with shared accountability for success.
- Evaluation of SPSD effectiveness

These elements are addressed by enhancing MESA with SPSD: MESA is an exemplary academic support model and SPSD provides a focus on professional preparation. Table 2 shows the activities supported by each program.

Table 2. SPSD and MESA Activities

MESA Activities	SPSD Activities
Individual Academic Plans	Leadership Summit
STEM Course Clustering	StrengthsQuest
Academic Excellence Workshops (AEW)	Training Academies for Industry Skills
Tutoring	Job Shadow Day
College and Career Exploration	Summer Team Internship Program
College Orientation Course	Faculty Advisors
Transfer Assistance to Four-year Universities (2-year colleges only)	Scholarships/Participation Stipends
Assistance Applying to Graduate Schools (4-year universities only)	STEM Competitions
Scholarships	San Diego Region Joint Planning Conference
Collaboration with Student/Professional Organizations	

The MESA model provides the following academic support to students to raise their performance and improve their academic achievement:

Individual Academic Plan and Academic Advising - SPSD students receive academic advising at least once per semester that helps them develop an individual plan of study. By developing an Individual Academic Plan and monitoring it each semester, SPSD students are on the right track towards completing general education and major requirements in the precise timeline for graduation. Focused advising is also provided to help students with career and graduate education decisions by means of a designated academic counselor.

In addition to academic advising, SPSD students receive assistance with personal counseling. Existing MESA counselors help students to access the campus resources needed to work through emotional, financial, and family difficulties to stay on track for graduating.

Cluster Classes, Academic Excellence Workshops (AEW's), and Tutoring - Several strategies are used to help SPSD students achieve academic success. The clustering and AEW's are based on the Uri Treisman study of minority student performance in first year calculus[17]. SPSD students at the university level are clustered together in core STEM courses (mathematics, chemistry, physics and engineering) to lessen feelings of isolation and promote participation in study groups.

AEW facilitators meet with the course instructor who guides the workshop content. SPSD students participate in the MESA small-group AEW's. The workshops provide supplemental course instruction via group study sessions facilitated by high achieving upper division students. Participants work collaboratively to learn study and networking habits and reinforce the material from core STEM courses by practicing problem solving techniques. Students are instructed in the use of effective academic achievement skills, including group study, note-taking, reading for retention, etc. To complement classes and AEWs, one-on-one tutoring is provided by older students (as part of their community service, paid hourly workers or work study students) to enhance the students' likelihood of success.

College and Career Exploration - The SPSD facilitates college and career exploration for students each semester. Guest speakers are scheduled to discuss university and career opportunities. The SPSD promotes and/or facilitate professional development activities such as: on-campus job fairs, industry mentors, job shadowing, field trips, etc. SPSD students are assisted to develop skills pertinent to securing internships, employment opportunities and graduate admissions in STEM-related fields.

Orientation to Higher Education and Assistance with Transfer and Graduate School Admissions - Community college and university partners utilize the existing MESA student centers at their respective campuses which provide a multipurpose student center to support a community of learners. The student centers are a critical on-campus home base for SPSD students. SPSD staff members are on-hand to provide direct support to students. The SPSD program also provides intensive support to first-year university students. Using the MESA model, an orientation course is offered that assists SPSD students with the transition to the new environment of higher education. The course reviews effective study skills, explore career options, and assist in developing a network among students in order to foster an attitude of mutual support. At the community colleges orientation is offered in group or individual sessions rather than a semester long course.

Scholarships – Numerous scholarship opportunities are disseminated and promoted to MESA students.

Collaboration with Student/Professional Organizations - The SPSD promotes student participation in student chapters associated with professional organizations, including (but not limited to) the Society of Hispanic Professional Engineers (SHPE), National Society of Black Engineers (NSBE), Society of Women Engineers (SWE) and Association for Women in Science (AWIS). Participation in

student chapters provides leadership opportunities, connections to professionals and opportunities for community service.
Building on MESA, SPSD provides the following professional and leadership development activities, not addressed in the classroom curriculum:

Leadership Summit – A weekend camping event with an agenda of seminars, workshops, and group projects designed to develop the leadership, communication & presentation skills of SPSD students. The summit fosters a community of engineers/physical science students who utilize the skills learned as they navigate their home campus and share these skills by teaching others (peers and pre-college students) what they've learned.

StrengthsQuest - A personal strengths assessment of SPSD students is taken using the nationally recognized StrengthsQuest tool developed by the Gallup Organization. The strengths assessment is used to adapt the activities to the strengths and needs of the students. In particular, the use of the StrengthsQuest assessment is integral to the activities of the Leadership Summit and to Orientation.

Training Academies for Industry Skills - are conducted by industry professionals during the academic year to train SPSD students in the skill sets that are currently in demand by industry, but many times not taught in the classroom. For example: Six Sigma, Lean Manufacturing and Microstation. Industry partners such as Hamilton Sunstrand and CALTRANS provide this training to better qualify SPSD students for internships and employment opportunities.

Job Shadow Day – allows students to shadow a professional engineer, scientist, or medical professional in their field of interest. Students experience firsthand what a professional does in a typical work day. Participating companies include QUALCOMM, CALTRANS, IBM, Hewlett-Packard, SONY, Hamilton Sundstrand, County of San Diego, City of San Diego, Rick Engineering and many other private and public companies.

Summer Team Internship Program - The SPSD facilitates a 100-hour summer internship program for more than 36 SPSD students per summer. Mixed teams of 2-4 community college and university students participate in multi-week team internships at industry sites. Participating companies such as PBS&J and SONY interview and select interns on the basis of their successful completion of the SPSD industry based standards. Interns receive a $1,250 stipend. Experience in research laboratories with faculty is also available. The internship experience is a major component of this project. A full-time project coordinator facilitates this activity which requires time to maintain relationships with industry representatives in the IAB as well as time to recruit new relationships.

Faculty Advisors - The SPSD promotes faculty participation and accessibility by compensating them for help sessions, SPSD related lectures (i.e. 'majors meetings' where faculty meet with students and their families to describe opportunities in their respective fields) and mentoring.

Scholarships & Participation Stipends - SPSD promotes scholarship. The majority of SPSD students have difficulty covering all educational expenses, even with financial aid. The scholarships and internships help SPSD students to reduce unrelated outside work hours, and focus on academic coursework, which increases retention, improves overall academic performance and increases the probability of degree attainment. Companies from the IAB have committed to providing scholarships and/or internships. In addition, 20 students from each community college and 40 from the university earn a $500 participation stipend for achieving a high number of activities.

STEM Competitions: Team Events

A. Engineering Design and Test: Walk-on-Water Competition - SPSD hosts an annual Walk-on-Water competition at Southwestern College. The competition requires the design of "buoyancy shoes" to cross the length of a swimming pool in a timed event against other "pilots". Awards are given for Fastest Shoes, Most Creative Design, and Most Resourceful Design (use of recycled materials). The MESA Pre-College students are also invited to compete.
B. Engineering Design and Test: Robotics Challenge - SPSD hosts an annual Robotics Challenge. Each SPSD campus sponsors at least one robotics team. The student teams design and program multifunctional robots using LEGO Mindstorm Robotics kits. Awards are given for winners of each of the two events. The MESA Pre-College students are also invited to compete.
C. Academic Development: Calculator Olympics - In conjunction with the robotics competition, SPSD hosts an annual Calculator Olympics. Teams of four students, from community college and university will compete in three academic levels by solving technical problems in mathematics, chemistry, physics and engineering. Prizes are awarded in each of the three levels: beginner, intermediate, and advanced. Industry sponsors such as Sony donate prizes for winning teams at each level. Industry partners [IAB] volunteer as judges. The MESA Pre-College students are also invited to compete.

San Diego Region Joint Planning Conference for Engineering & Science Student Chapters-Prior to each academic year, the SPSD organizes an annual Joint Planning Conference (JPC) for Engineering and Science Chapters. The event is hosted by IAB member companies such as QUALCOMM, Raytheon, and Rick Engineering Company. The JPC assembles students and professionals from engineering and science organizations enhancing the professional development of tomorrow's STEM leaders improving chapter effectiveness, increasing communication between stakeholders - students, industry and SPSD staff, - and promoting leadership development.

Therefore, with the guidance of industry representatives, the SPSD principal partners build upon the best practices from the MESA Program to establish a comprehensive inventory of standards for the student academic, personal, and professional development of SPSD students. Completion of industry-based standards (see Table 3 on next page) complement classroom curriculum, enhance workforce readiness and is the basis for student participation in the SPSD Program. The IAB was instrumental in developing the standards. These SPSD standards are organized into five critical areas for student development: *Counseling*, *Academic Support*, *University Bridging, Industry Exposure* and *Community*. These activities are tracked using a MESAdvantage Report Card, see Appendix 1: MESAdvantage Report Card.

These standards represent a proactive guidance plan for student development across the SPSD pipeline for the purpose of addressing each of the five goals of the project. Students are required to maintain a portfolio to be reviewed by the respective SPSD PI that contains documentation to verify completion of each standard. This ensures student accountability and maintains a level of quality in all SPSD participants. Each year a $500 participation stipend is provided to up to 80 students for successful completion of the SPSD standards.

Table 3. SPSD Student Standards; based on industry needs.

1. COUNSELING	
Required—Participating students must:	***Optional—Participating students may choose to:***
o Complete educational plan o Meet with counselor once per semester to review progress in major o Contact university advisor to confirm 4-year plan	o *None*
2. ACADEMIC SUPPORT	
Required—Participating students must:	***Optional—Participating students may choose to:***
o Complete SPSD orientation course o Participate in Academic Excellence Workshops (AEW) & Course Clustering o Receive tutoring (required if GPA < 2.5) o Complete progress report each semester o Complete time management plan each semester o Apply for scholarships/financial aid on a yearly basis	o Serve as AEW facilitator or tutor o Act as a peer mentor o Attend academic seminars (i.e. junior/senior seminar)
3. HIGHER EDUCATIONAL ADVANCEMENT (UNIVERSITY BRIDGING)	
Required—Participating students must:	***Optional—Participating students may choose to:***
o Research opportunities for educational advancement o Establish connections at prospective institutions o Contact university students in major (minimum 1) o Campus tour	o Participate in university workshops and conferences o Attend university STEM class (community college only) o Explore and participate in research opportunities
4. INDUSTRY EXPOSURE	
Required—Participating students must:	***Optional—Participating students may choose to:***
o Join a student chapter o Create resume and cover letter o Develop interview skills o Research companies o Conduct informational interviews (minimum 2) o Take industry tours o Attend a job shadow experience	o Work with an industry mentor o Serve as student chapter officer o Engage in mock interviews o Volunteer o Work in an internship o Attend industry workshops and conferences (such as SPSD Saturday Academies)
5. COMMUNITY	
Required—Participating students must:	***Optional—Participating students may choose to:***
o Perform approved educational/engineering related community service (15 hours min per semester)	o Tutor/mentor peers

Results

Four years into the program, SPSD is persistently succeeding to increase student participation and improve the achievement of URM students in STEM majors assisting them to excel academically and prepare for the STEM workforce. Each SPSD partner campus has also increased enrollment by at least 10% each year of the project. Furthermore, 3rd year data indicates that the five SPSD goals are being met. The SPSD data is collected by an outside evaluator, Institute of Public Health (IPH). IPH also has responsibility for developing a tracking system, analyzing data, and reporting on project activities and goals. IPH tallied and analyzed evaluations completed by students regarding the SPSD activities in which they participated. These evaluations reveal that the activities are having the intended positive impact on students. For example, on a scale from 1 -4, where 4 is excellent and 1 is poor, 95% or more of students that attended the Leadership Summit reported that their experience made them a better leader; and for the Joint Planning Conference, 97% or more of students reported that they were better able to serve as a student leader in their respective organization. Moreover, on average, 90% of students that attended professional development activities such as Shadow Day, Training Academy, and Internships reported that they were better prepared to enter the STEM workforce. Following are preliminary results for each of the project goals:

Goal 1: Expand participation in SPSD and MESA activities.

- Related Objective: Enrollment at each institution will increase by 10% annually.
- Progress: This objective has been met and surpassed by each partner institution, every year of the grant. Overall, enrollment in SPSD has increased from 443 students in 2007 to 587 in 2009. This represents a total increase of 33%. (Figure 2)

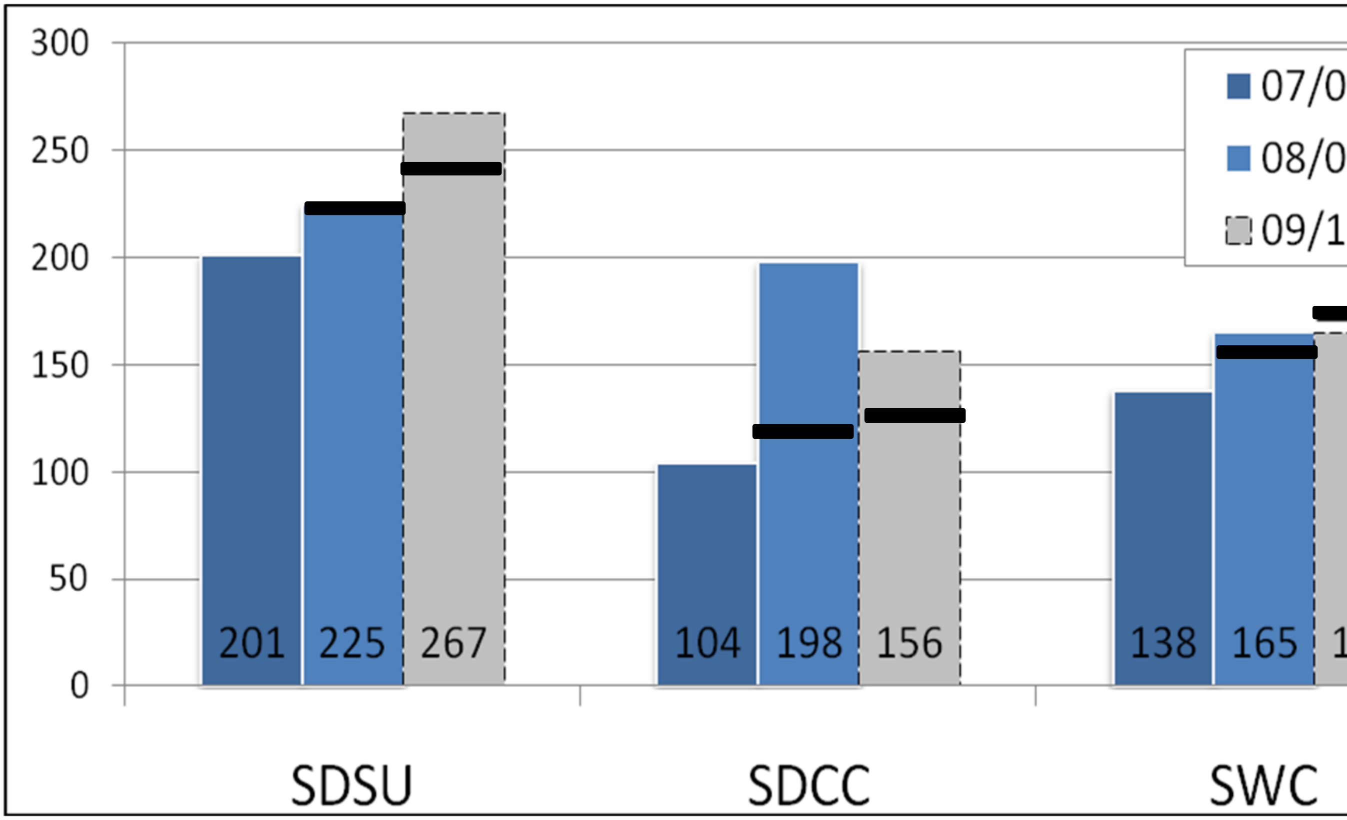

Figure 2. Targets (lines) and actual enrollment (bars) at each SPSD partner institution

Goal 2: Improve the retention of SPSD/MESA students

- Related Objective: At least 350 students will be enrolled in SPSD/MESA from declared major through transfer or graduation.
- Progress: To date, there have been 83 graduates from SDSU, 27 transfers from SDCC, and 59 transfers from SWC. This puts SPSD at about 48% of their Goal with 587 current enrollees who have yet to transfer, graduate or leave the program.

Goal 3: Increase the number of SPSD/MESA students graduating with B.S. degrees

- Related Objective: At least 160 SPSD/MESA students will graduate with a B.S. degree in a STEM major.
- Progress: With 33 graduates in 2008, 20 graduates in 2009, and 30 graduates projected in 2010, SPSD is 77 graduates away from meeting the objective with two graduation cycles left in the grant; suggesting this goal will be achieved or surpassed.

Goal 4: Provide STEM industry internship opportunities to an increased number of SPSD/MESA students

- Related Objective: At least 36 SPSD/MESA students will complete an internship or research opportunity each year.
- Progress: This Goal was exceeded in each program year, see Figure 4. Eighty new internship opportunities were created through SPSD, including new research opportunities for students at each SPSD partner institution, see Appendix 2: Industry Internships and Research Programs. In addition, 33% of each summer cohort continued working for their host company after the completion of their internships.

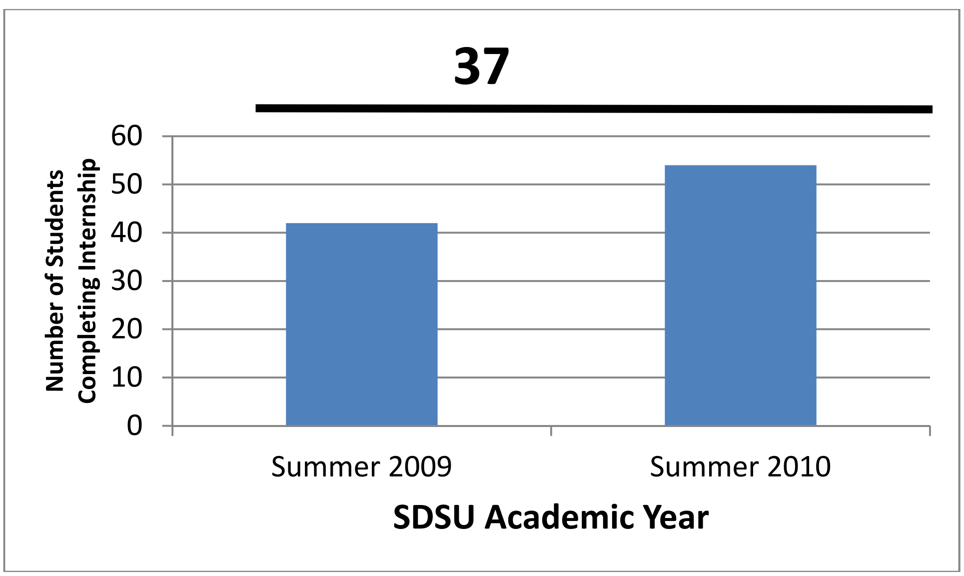

Figure 4. Target (36) and actual participation in Summer Team Internship program

In statements made by the SDG&E Chief Operating Officer and the SDG&E Director of Electric Transmission & Distribution Engineering, *SPSD/MESA students stand out in interviews; they not only spell out the program on their resumes, but they engage in conversation and talk passionately about their participation in the program.*

Goal 5: Promote post-graduate study opportunities for SPSD/MESA students

- Related Objective: At least 15 graduating seniors participating in the SPSD program will enter STEM graduate study programs by the end of the grant period.
- Progress: As of spring 2010, eight SPSD/MESA students have enrolled in STEM graduate study programs at SDSU. Data suggests this goal will be met or surpassed with three graduation cycles remaining.

Beyond the five SPSD goals, substantial student achievement has resulted at each SPSD partner institution:

San Diego State University

- Fall 2007 to Fall 2009, 89.3% of SPSD students taking courses supplemented with AEWs passed with C or better vs. 70.1% of SPSD students who did not attend AEWs. In addition, 77.7% of non-program students who attended AEWs passed their classes with a C or better. Furthermore, 58.1% of SPSD students taking courses supplemented with AEWs passed with B or better vs. 35.3% of SPSD students who did not attend AEWs.
- Average GPA of SPSD students has increased each year of the project. in each project year, the average GPA of SPSD students is higher than the average GPA of non program students. This GPA result is also true for students in the cases of students of color and of women, when comparing SPSD students vs. non program students.

Southwestern College

- During the first two years of the project, SPSD/MESA students outperformed STEM students in GPA
- Average GPA of transferring SPSD/MESA students has increased each year of the project
- 89% of the STEM scholarship awards are earned by SPSD/MESA students

San Diego City College

- In Fall 2009, successful SPSD/MESA students had an average GPA of 3.07
- In Fall 2009, 100% of SPSD/MESA students passed Calculus II compared to 29% of non-program students in the same class
- In the first two years of the project, 83% of transferring SPSD/MESA students have attended local universities

Broader impacts have resulted from the SPSD project at the partner institutions. Where possible, non program students have been invited to participate in and benefit from SPSD activities. Faculty have also benefited from the project. Specifically at San Diego City College , resources and tools in the MESA ‘Foundation for Learning’, originally developed to increase the success of SPSD students, have been disseminated to and utilized by STEM and non-STEM faculty campus wide.

Summary & Future Work

For over 40 years, the MESA program has been a model for student success in STEM fields. The basics of the program are effective in all levels of educational settings from K-12 to university. Three MESA programs in San Diego, two community colleges and one university, expanded on the effective MESA model through an NSF grant award, namely SPSD. The grant enabled the San Diego MESA team to implement activities, identified as standards by industry partners, which serve to prepare students to enter the STEM workforce. These standards, as tracked by a MESAdvantage Report Card, ensure that students are empowered by developing academic skills, learning leadership skills, and gaining industry-relevant experiences. Moreover, the industry partners, through an Industry Advisory Board, provide necessary guidance for program development and are vested in the success of the MESA program.

Based on current results, the SPSD project is on track to meet overall goals. However, the SPSD is a comprehensive project, with many activities. Further evaluation is necessary to identify which activities are most effective. The SPSD partners, along with IPH, will implement an enhanced evaluation plan to pinpoint which of the activities are most impactful on student success. This information will be critical for replication of the SPSD project. In addition, all SPSD outcomes and lessons learned will be captured in a "Guide to an Effective STEP." The Guide will provide the foundation for developing a STEP Program, including best practices, techniques, evaluation results, and anecdotes from students, alumni, industry representatives, and program staff. The Guide will be disseminated nationally for use by other programs. In summary, it is the authors' intent that this outstanding model of success comprising the MESA guidelines, positive collaboration among leaders and leveraging programs with federal and /or private funds will be adopted by others to resolve our national needs. In summary, it is the authors' intent that this outstanding model of success comprising the MESA guidelines, positive collaboration among leaders and leveraging programs with federal and /or private funds will be adopted by others to resolve our national needs. In summary, it is the authors' intent that this outstanding model of success, comprising the MESA guidelines, positive collaboration among education and industry leaders, and leveraging programs with federal and /or private funds, will be adopted by others to address our national needs.

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Appendix 1: MESAdvantage Report Card

San Diego MESA (Mathematics Engineering Science Achievement) Alliance

MESA*dvantage* Student Report Card **Year:** ____________________

Student name: ________________________________ **School:** __________________

	Industry Based Standards - Student Activity Checklist	Date Completed	Director Eval
University Bridging (Networking)	Participate in MESA Networking Events (e.g. Jr. Shadow Day, Transfer visits, Banquets, etc)		☐
	Research opportunities for educational advancement		☐
	Establish connection with prospective educational institutions (e.g. with student support services, with student clubs, or with a university advisor)		☐
	Enroll in a class (in major) at prospective transfer institution		☐
	Explore and participate in field or lab research opportunities		☐
	Take SAT or GRE (MCAT, DAT, etc) prep class and exam, apply to college or grad school		☐
	Other: ______________________________		☐
Counseling	Meet with counselor once per semester to review progress in major*		☐
	Complete semester by semester plan of classes required to transfer or to graduate*		☐
	Complete time management plan each semester*		☐
	Complete *StrengthsQuest* assessment		☐
	Other: ______________________________		☐
Academic Support	Complete MESA Orientation course/workshop/Saturday Academy*		☐
	Participate in Academic Excellence Workshops		☐
	Attend academic seminars		☐
	Compete in MESA competitions (e.g. MESA Days, MESA Olympics, Walk-on-Water, etc.)		☐
	Seek additional academic support (e.g. tutoring)		☐
	Participate in Peer Mentoring		☐
	Serve as AEW Facilitator or MESA Tutor		☐
	Apply to at least one scholarship program each year*		☐
	Other: ______________________________		☐
Community	Participate in organized educational community service programs (e.g. MESA Days, Granger Event, etc.)		☐
	Participate in organized non-educational community service programs (food drives, clean-up San Diego, etc.)		☐
	Tutor/Mentor others		☐
	Other: ______________________________		☐
Industry Exposure	Resume, Cover Letter and reference list*		☐
	Participate in Job or Mock or informational interviews*		☐
	Join a professional or student organization (e.g. NSBE, IEEE, PASE, SHPE, SWE, etc.)		☐
	Serve as student chapter officer		☐
	Attend Industry Training Academy		☐
	Attend Professional Development Seminar(s) and activity(ies)* (e.g. summit, interview skills, Science Opportunity Day, Joint Planning Conference-JPC, tours, etc.)		☐
	Research Companies*		☐
	Job Shadow Industry professionals at work		☐
	Obtain industry mentor		☐
	Obtain experience via internship or volunteerism		☐
	Other: ______________________________		☐
Director's Evaluation: ______________________________			

Notes: * Documentation available

Director signature **Date** **Student signature**

STEP Partnership of San Diego (SPSD), 7/2008

Appendix 2: Industry Internships and Research Programs (2008, 2009 and 2010)

Alere**
Assure Controls Inc**
Biotechnology Education & Training Sequence Investment (BETSI) Project at Salk Institute and at Scripps Research Institute**
Bridges to the Future**
Caltrans*
City of Los Angeles Bureau of Sanitation
Dexcom**
Fleet Readiness Center Southwest
Fqubed Inc**
General Atomics Electronic Systems, Inc
Howard Hughes Program*
Infrastructure Engineering Corporation*
Kennedy/Jenks Consultants
Malcolm Pirnie
National Oceanic and Atmospheric Administration
Naval Air Systems Command*
Naviscan Inc**
Northrop Grumman Corporation
Raytheon Company
Regional Water Quality Control Board
REU, University of Minnesota**
Rick Engineering Company*
San Diego Coastkeeper*
San Diego Natural History Museum
San Diego Water Department
San Diego Zoo
SDSU Global Change Research Group**
Sempra Energy
Shiley Center for Orthopaedic Research & Education at Scripps Clinic**
Short-Term Education Program for Underrepresented Persons**
SMDEP, University of Washington**
Southern California Biotechnology Center**
SouthWest Water Company
SPAWAR Systems Center San Diego*
Spectrum Scientific, Inc**
Summer Undergraduate Research Fellowship Program**
UCSD Laboratory of Sleep and Chronobiology*
UniversityLink Medical Science Program**
Research City: Professor Misael Camarena**
Research City: Professor Rafael Alvarez**
Research SDSU: Dr. Diane Smith**
Research SDSU: Dr. Gordon Lee**
Research SDSU: Dr. Joseph Lewis**
Research SDSU: Dr. Khaled Morsi**
Research SWC: Dr. David Brown**
Research SWC: Dr. R. Bakhiet, Dr. L. Buehler, Dr. D. Hecht**

* Companies that provided internship opportunities to MESA students in 2008, 2009, and 2010

** Faculty Research Projects or Biotechnology Internships

Structural Engineering for Architecture and Construction Management Students

James Guthrie, SE
California State Polytechnic University
San Luis Obispo

Introduction

Architecture and construction management students can often graduate with a weak foundation in structural engineering leaving them less than fully prepared to take on their future roles in industry. The California Polytechnic State University in San Luis Obispo (Cal Poly) is well positioned to fill this potential gap. The Architectural Engineering (ARCE) Department at Cal Poly is fortunate to be one of five departments located within the College of Architectural and Environmental Design (CAED) a college that also includes the Architecture (ARCH) and the Construction Management (CM) departments. A great benefit of this arrangement is that considerable interaction takes place amongst the departments mirroring the interaction and collaboration that occurs in industry. One of the more successful interdepartmental collaborations has been amongst the architectural, construction management and architectural engineering departments. This exchange of information and students encourages greater knowledge and understanding of each other's disciplines and prepares students for a practice that increasingly values such interdisciplinary collaboration.

The ARCE department offers a sequence of five support courses that are taken by architecture and construction management students and gives them a solid grounding in statics, properties of materials and structural systems. The final two courses in this sequence are titled *Small Scale Structures* and *Large Scale Structures*. These two courses are unusual in that they are designed not for ARCE students but solely for the ARCH and CM students.

In presenting these two culminating courses, this paper addresses the background of the support course sequence, the role these two courses play in the five course sequence and their goals, learning outcomes, content and methodologies and approaches. This paper will also describe the interdepartmental assessment processes and how these two unusual courses show successful strategies for providing cross-discipline education.

Background and the Five Course Sequence

The curriculums for the ARCH and CM students at Cal Poly have, for many years, included structural engineering courses taught by the ARCE department. In 2005 the ARCE department updated the sequence of courses required for the ARCH and CM students. The earlier six course sequence, which included three structural material specific design courses, was replaced by a five course sequence in which the three material design courses were replaced with two courses focused on small scale and large scale structures.

As restructured, the curriculum for ARCH and CM students now includes a total of five ARCE courses giving them a solid grounding in structural engineering principles, design and systems. The five one-quarter courses, with the number of units and hours each week, are listed below:

- *Structures I (3 units with 2 hours of lecture and one hour of activities per week)*
- *Structures II (3 units with 2 hours of lecture and one hour of activities per week)*
- *Structural Systems (3 units with 3 hours of lecture per week)*
- *Small Scale Structures (4 units with 4 hours of lecture per week)*
- *Large Scale Structures (4 units with 4 hours of lecture per week)*

The first two courses, *Structures I* and *Structures II*, are taken by ARCE as well as ARCH and CM students. These are rigorous courses that introduce statics and the mechanics of materials. These two classes combine traditional lectures with activity sessions in which students build physical models to enhance their understanding of the content. *Structures I* is an introduction to statics and the creation of simple three-dimensional structures. Skills to analyze structures composed of axial force members are developed. *Structures II* is an introduction to shear and moment diagrams using the principles of statics and the application of the diagrams to simple three-dimensional structures. Skills to analyze structures composed of bending (beams) members particularly, free body diagrams, are developed.

Following *Structures I* and *Structures II*, is a course entitled *Structural Systems*. This course is for ARCH and CM students only. This is the course in which the focus shifts from elements to building structures. Building on the skills learned in *Structures I* and *Structures II*, students develop the skills to analyze simple buildings composed of axial and bending members. They learn about structural stability, gravity and lateral loads, the development of framing plans, the behavior and comparison of structural building systems, framing schemes and building configuration related to vertical and lateral loads.

Following the *Structural Systems* course, the ARCH and CM students take a *Small Scale Structures* and then a *Large Scale Structures* course. The *Small Scale Structures* course focuses on timber and single story steel framed buildings. The *Large Scale Structures* course focuses on multi-story reinforced concrete and structural steel framed buildings. Students learn the characteristics, advantages and disadvantages of different structural systems, how to evaluate the different systems and how to develop the preliminary structural designs of buildings. The courses also cover foundations, cladding and long span and high rise structures.

The primary goal of this series is to give these students tools that will assist them in their careers as project leaders so they can better produce efficient integrated designs and collaborate effectively with their structural engineering consultants and therefore lead more successful projects.

The benefits of understanding structural principles apply to both ARCH and CM students. Architects typically take a lead role in building design and so an understanding of structural principles can enhance their ability to produce design concepts that are coordinated with an efficient, well thought out structural system. Understanding structural concepts and nomenclature allows the architect to more effectively communicate with their structural consultants and better develop the structural system. In addition, the architect, as team leader, often has the direct communication with the client or owner and a better understanding of structural principles allows them to better communicate structural principles and the implications of structural decisions to the owner. The decisions of an informed owner are more likely to result in a successful project. An understanding of structural engineering principles acquired as an architecture student can therefore be of great benefit in his or her career.

These courses are of similar benefit to CM students. Construction managers are increasingly involved during the design phases of projects. In projects that use a design-build process, they often also act as team leaders. For them, knowledge of structural principles also enhances their ability to collaborate with the structural consultants, better communicate with owners and help make effective structural decisions. Construction managers are often involved in developing construction costs. A clearer understanding of the implications of structural decisions can be of great value.

An additional benefit of these courses to students is that they encourage interdisciplinary collaboration. This occurs between the ARCH and CM students in the classroom and also with the ARCE faculty. Although informal, it is not uncommon for ARCH and CM students to consult with their ARCE faculty regarding structural systems for their studio projects.

Learning Outcomes & Outlines

The learning outcomes of the two culminating courses, *Small Scale Structures* and *Large Scale Structures*, are based on the overall goal of giving the ARCH and CM students the structural engineering skills and the understanding of structural engineering principles that will serve them in their careers as project leaders. The learning outcomes have been defined to include content with an appropriate level of structural engineering rigor and to accommodate the architectural and construction management disciplines, by including a balance of architectural design and construction issues. The learning outcomes have been repeated below:

Small Scale Structures – Learning Outcomes

Upon completion of this course, a student should have the ability to:

1. Trace the load path for both gravity and lateral loads in a small-scale structure
2. Design beams and columns to meet strength and service-ability criteria specified in the building code using wood and steel.
3. Conceptually understand the design of horizontal diaphragms to meet design criteria specified in the building code for wind and seismic loads.

4. Understand the behavior and design of steel and timber lateral load resisting systems in a flexible diaphragm structure.
5. Understand conceptual principles about connection design.

Large Scale Structures – Learning Outcomes

Upon completion of this course, students should have:

1. Ability to develop preliminary gravity and lateral load resisting systems in medium and large scale structures.
2. Ability to trace gravity and lateral load paths in medium to large scale structures.
3. Ability to determine preliminary beam and column sizes to meet strength and serviceability criteria.
4. Awareness of connection design concepts for structural steel and reinforced concrete in rigid diaphragm systems.

Although the learning outcomes are somewhat general, the outlines for these two courses include a significant amount of structural content. The structural content in the course outlines includes: the development of vertical and lateral loads, gravity and lateral configuration issues, gravity and lateral structural systems, rigid and flexible diaphragm behavior, timber, steel and concrete material properties, the design of timber, steel and concrete gravity systems, an understanding of timber, steel and concrete lateral systems, structural material finishes and connections, tall buildings, long span structures, cladding and deep and shallow foundation systems.

These course learning outcomes and outlines reflect a rigorous architectural engineering approach that the ARCE faculty believed was appropriate for the course. However the classes have typically also included content and approaches intended to both inspire the ARCH and CM students and provide skills specific to their future careers. This is reflected in the methodologies used by individual instructors.

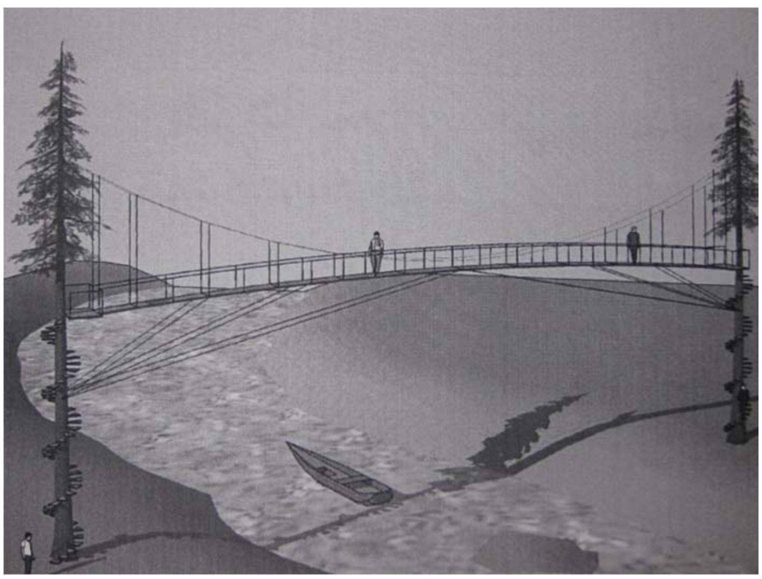
Methodologies

Several types of classroom methodologies have been used by instructors. All have been successful in meeting the learning outcomes and covering outline topics. However each has done so in different ways reflecting instructor's backgrounds and providing a diversity of student experiences. These methodologies include graphic analysis, computer modeling, physical model building and individual and team projects. The types of class materials varied with the type of activity used in the classroom. In general, textbooks were not used and each instructor used materials developed from his or her experience. The different methodologies are described below.

<u>Graphical Analysis</u> methods for the design of curvilinear and long span structures was one approach used for the *Large Scale Structures* course. The graphical method used is a venerable part of structural engineering tradition, beginning with Karl Culmann's *Die graphische Statik* from 1864. It has more recently been championed by Allen and Zalewski in their 2010 book

Form and Forces. The use of graphical statics in a modern engineering course readily allows students to see how structural form and structural forces are inescapably intertwined. This is a rigorous, yet visual approach to the design and analysis of these special structures that worked well with both the architectural and the construction management students. A representative assignment was the design, using graphical statics, of a 110 foot span, cable supported footbridge. The analysis and design was performed by all students, with three dimensional renderings executed by the ARCH students and construction sequences described by the CM students.

This approach provided a visual and somewhat intuitive approach to the preliminary design of special structures that these students will employ in their careers. It is also especially appropriate for the curvilinear structures that may not lend themselves to simple manual calculations. The approach of assigning different tasks to the architectural and construction management students recognized their strengths and encouraged interdisciplinary collaboration.

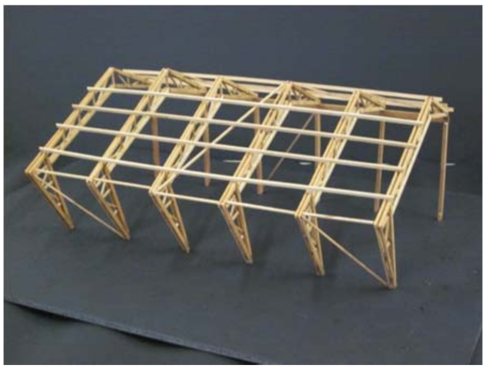


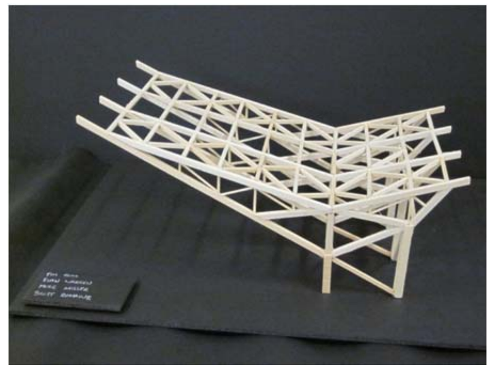
(image by Ed Saliklis)

Computer Analysis was one methodology used for the tall buildings module of the *Large Scale Structures* course. The tall building module included a review of the history and development of tall building structural systems as well as a review of the behavior of the structural systems now in use. A review of the structural trends in tall building construction over the last 130 years from masonry to moment frames, braced frames, tube and outrigger systems as well as a contextual description of the engineers who developed these designs provides an appropriate level of structural literacy appropriate for future project leaders. Such a historical review, tracing the actual engineering ideas created by key engineers is another means of making the principles of structural behavior come alive to the students. After visual presentations of the fundamental principles of tall building behavior, students prepared elementary computer models of buildings with outrigger systems as well as models of buildings using dual braced frame-moment frame systems. The intent of this approach was not for the students to acquire computer analysis skills, but for them to understand, from their own work, structural principles such as the different deformation patterns of braced frames and moment frames and the load sharing benefits of outriggers in tall buildings. A useful feature of the computer models is the ability to exaggerate the deformations, thus driving home what might be an otherwise too subtle distinction between, for example, shear behavior and cantilever behavior.

Physical Models have been used in the *Structural Systems*, the *Small Scale Structures* and the *Large Scale Structures* courses.

In the *Structural Systems* course, models have been used to demonstrate principles of stability and configuration for structures composed of axial as well as flexural members.



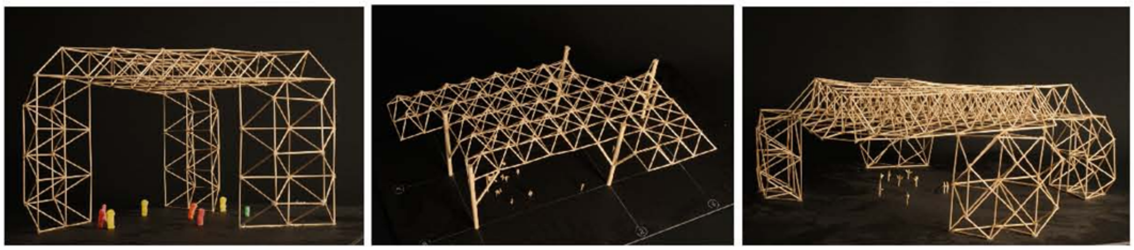


Structural Systems Course Models

In the long span module of the *Large Scale Structures* course, students worked in groups of three or four to design and construct one-way long span models using wood applicator sticks and dowels. The objective was to have the students understand the requirements in making closed section trusses and to explore the resulting possibilities.

Large Scale Structures Models (photos by Jake Feldman)

In a later assignment on space frames, students were introduced to the variety of geometric patterns that can be employed along with the support options that result in stable structural configurations. The students then designed and built models of a large covered space and experienced the visual and construction complexities resulting from choosing a space frame systems.



Large Scale Structures Models (photos by Jake Feldman)

Students also used physical models in a study of domes. A variety of geometries related to single layer domes were introduced along with the concerns for overall configuration stability. The models demonstrated the structural efficiency of domed geometries along with the visual nature of the spaces created.

Students also created scale models of reinforced concrete. The possibility of students being able to take coursework that includes the construction of scale model buildings out of reinforced concrete is an educational opportunity unique to Cal Poly. Over a period of several weeks student teams designed and constructed reinforced concrete buildings in a 48 foot long sand-filled casting table. This activity has many educational benefits:

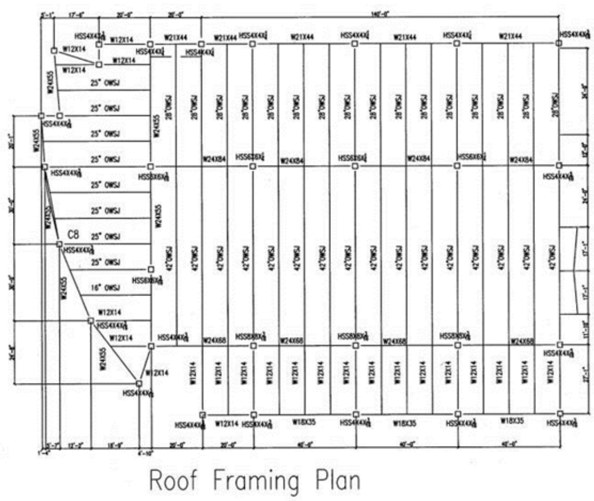
1. The students dealt with the possibilities and problems inherent in the use of reinforced concrete from the design through the construction phases.
2. The ability to design in concrete required an understanding of construction sequencing and continuity. By going through the process, the students were better prepared to understand how to “think in concrete”.
3. The students learned that concrete can be both the skin and the skeleton of the building.
4. The course very graphically introduced the students to the nature and necessity of foundations.
5. The students learned, at a small scale, the purpose and placement of reinforcing.
6. The students experienced the structural demands on formwork along with the difficulty of fabricating formwork, the nature of placing and finishing concrete, the anxiety and anticipation of removing formwork and the satisfaction and thrill of a successful pour.
7. Students began to learn the design tension between structural order and design freedom.

These are lessons that will stay with students throughout their careers.

Large Scale Structures Concrete Models (photos by Jake Feldman)

Samples of the students’ work are shown in these photos.

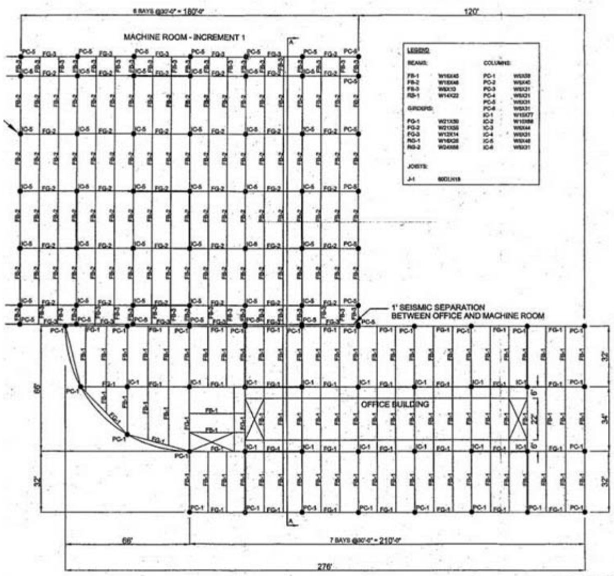
Projects, both team and individual, have been used in both the *Small Scale Structures* and the *Large Scale Structures* courses. The students produced preliminary structural designs for the types of building that they are likely to encounter in their careers. In the *Small Scale Structures* course these included a single-story school



Small Scale Structures – Representative Project

building, a middle school auditorium and a community college library. For the *Large Scale Structures* course, projects included a four-story, two building computer center and a four story public library. The projects were all based on actual buildings.

The students were given preliminary floor plans from which they prepared column and lateral system layouts. They then prepared preliminary structural designs for the gravity and lateral systems for the different structural materials presented in the course. In the *Small Scale Structures* course, alternate preliminary designs were prepared for structural steel and timber systems. In the *Large Scale Structures* course, alternate preliminary designs were prepared for structural steel and reinforced concrete systems. The preparation of the preliminary member designs used simplified design methods and rules-of-thumb.



Large Scale Structures – Representative Project

At the end of the quarter, students compared the alternate systems, developed systems recommendations and presented their conclusions to the class.

This project approach reinforced lectures on structural configuration, preliminary framing design and the evaluation of alternate structural systems. It gave the students a connection between the classroom work and actual building projects, an introduction to the comparison and selection of alternate structural systems and a feeling for structural framing sizes that should serve them well in the future. Sample framing plans and photos of the buildings on which the projects were based are shown.

Interdepartmental Assessment

An assessment of the five course sequence and especially the two culminating courses is now underway. The assessment includes reviews by the ARCE faculty and surveys of ARCH and CM students as reported by architectural and construction management faculty. The architecture and construction management faculty while recognizing the value of the ARCE five course sequence have reported a variety of recommendations and comments from their students. The ARCH students liked the physical models and enjoyed the presentation of famous building studies. They also liked the emphasis on the design aspects and the holistic discussion of load path, bracing layout and an understanding of how structures work.

The CM students liked the interdisciplinary aspect and wanted to understand the cost, schedule and constructability aspects of different structural systems. They were interested in the integration of systems such as superstructure, foundations, cladding, etc. The courses sometimes contained significant calculation content and although they may object to being treated like

ARCE students, they said they don't mind the rigor and calculations when they can see the benefit.

Both the ARCH and the CM departments reported inconsistencies amongst instructors. Given the range of methodologies, this was not surprising to hear. However we believe there is value in this variety.

The ARCE faculty review now underway reviewing the learning outcomes, outlines and methodologies for these two courses is expected to provide additional guidance to ARCE instructors.

Conclusion

We believe this five course sequence of support courses provides the college's ARCH and CM students an understanding of structural principles and systems that will serve them well in their future careers. This understanding of structures will allow them to produce design concepts that are coordinated with efficient well thought-out structural systems and it will enhance their ability to make decisions that have structural implications, encourage better collaboration with their structural consultants and allow them to better communicate structural issues to the owner.

The department learning outcomes and content for these courses include the acquisition of basic structural knowledge and preliminary design skills. These may be met in a variety of ways and the instructors teaching the final two courses have exercised significant freedom in the methodologies employed in their classrooms. These methodologies have included graphic analysis, computer modeling, physical model building and individual and team projects with sometimes more than one approach used in a class. This variety of approaches provides those teaching the courses with a wealth of approaches to use in the classroom and may also provide other institutions with examples they may incorporate into their programs.

The ARCE Department, with the Architecture and Construction Management departments, is now reviewing the five support course sequence and especially the two capstone courses. The likely outcome will be to further define and reinforce learning outcomes and content but also to allow diversity in instructor methodologies and approach so instructors can teach to their strengths and incorporate approaches that best engage the students.

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Creating a Learning Community among Diverse Financially Needy STEM Students

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Abstract

Although many California Community College students from underrepresented groups enter college with high levels of interest in science, technology, engineering, and mathematics (STEM), the majority of them drop out or change majors even before taking transfer-level courses due to a variety of reasons including financial difficulties, inadequate academic preparation, lack of family support, poor study skills, and inadequate or ineffective academic advising and mentoring. In 2009, Cañada College, a federally designated Hispanic-serving institution in the San Francisco Bay Area, received a National Science Foundation Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM) grant to develop a scholarship program for financially needy community college students intending to transfer to a four-year institution to pursue a bachelor's degree in a STEM field. In collaboration with the College's Mathematics, Engineering, and Science Achievement (MESA) program – an academic, personal, and professional support structure has been designed and implemented to maximize the likelihood of success of these students. This support structure aims to create a learning community among the scholars through a combination of academic counseling and mentoring, personal enrichment and professional development opportunities, and strong academic support services. This paper describes how faculty, staff, administrators, alumni, student organizations, and partners in industry, four-year institutions, and professional organizations can be involved in creating an academic infrastructure that promotes academic excellence, leadership skills, and personal and professional growth among the diversity of financially needy STEM students in a community college.

1. Introduction

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. The College opened in 1968, and is located in Redwood City, California. During the 2009-2010 academic year, the College enrolled 11,566 students. The student body is genuinely multi-cultural with Hispanic students as the largest single group at 39.2%; white students comprise 33.3%, Asians 8.6%, African-Americans 3.8%, Filipinos 3.6%, Pacific Islanders 1.7%, American Indian/Alaska Natives 0.4%, other 9.5%.[1] Like all of the California Community College System institutions, Cañada is an open-enrollment institution, designed to welcome students of all ages and backgrounds to higher education. Cañada's Mission is to ensure that students from diverse backgrounds achieve their educational goals by providing quality instruction. Science, Technology, Engineering, and Mathematics (STEM) students from underrepresented groups and economically disadvantaged backgrounds receive academic support services from the College's Mathematics, Engineering, and Science Achievement (MESA) Program that has been a part of the College since 1999, and is part of the California MESA Program, a program that has received national recognition for its success.[2]

Nationally, community colleges are a gateway to higher education for large numbers of students, especially low-income students. Yet for many students, the community college experience 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.[3] According to the study, only 15% of African American students and 18% of Latino students completed a degree or certificate within six years, compared to 27% of white students, and 33% of Asian students. As STEM majors, African American and Latino students have lower success and retention rates at community colleges and universities. Comprising almost 25% of the U.S. population, African Americans and Latinos make up less than 7% of the individuals with B.S. or higher-degree holders in STEM fields.[4]

In 2010 in Silicon Valley, the distribution of high school graduates meeting University of California (UC) or California State University (CSU) requirements by race/ethnicity reveals that some groups are less prepared to enter college upon graduation. Only 24% of Latino and African American graduates met UC/CSU requirements compared to 68% of Asians and 52% of Whites.[5] This preparation gap is reflected in the results of the Cañada College's math placement tests over the last four years. Only 6% of African Americans and 8% of Mexican Americans are qualified to begin Trigonometry or higher when they arrive at Cañada College as compared to 21% of Caucasian and 23% of Asian American students.

Although nationally interest in science and engineering is lower for Latino, African American, and Native American students compared to other ethnic groups,[6] this is not the case at Cañada College. Table 1 summarizes the percentages of students taking the Cañada College math placement test and declaring STEM majors for the four largest ethnic groups for the last four years. Although Mexican Americans represent only 37.2% of all students who took the test, they represent 38.9% of students who declared a STEM major, and 46.2% of students declaring an engineering major.

Percentage of students who:	Mexican American	Caucasian American	Asian American	African American	Other
Took the Math placement test	37.2%	30.2%	5.7%	6.4%	20.5%
Declared STEM majors	38.9%	30.1%	6.9%	4.6%	19.5%
Declared Engineering majors	46.2%	27.8%	4.1%	3.6%	18.3%

Table 1. Summary of ethnic distribution of students who took the placement test, who declared STEM majors and who declared an Engineering major (April 2006-April 2010; 6,300 students).

Despite their interest in engineering, Mexican Americans represented only 19.4% of all students who transferred to a four-year school as engineering majors from 2005-2010 while African Americans were 0.9% of the engineering transfer students. In 2008, to help improve the success of these underprepared students, Cañada College applied for, and was awarded a National Science Foundation Scholarships in Science, Technology, Engineering, and Mathematics (NSF S-STEM) grant. The scholarship program will provide a total 140 scholarship awards of $3000 to $4000 per year for the five-year period of the grant, as well as academic and student support services to all scholars in order to help them successfully complete their lower-division requirements and transfer to a four-year university in a STEM major. This paper is a description of the results of the first two years of implementation of the program.

2. Cañada College's NSF S-STEM

An analysis of student data tracked by the Cañada College MESA Program over the last several years reveals that MESA students work an average of 15-20 hours a week to cover the cost of their education. In 2008, for instance, 65% of MESA students work 16 or more hours per week and 28% of MESA students work more than 26 hours per week. Because of the need to work while going to college, combined with low placement test scores, the vast majority of these students take at least three years to complete lower-division course requirements before transferring to a four-year institution. To better serve the needs of these students, four different award levels were developed for Cañada's S-STEM program. The first three levels are to support students' three-year tenure at the College, and the fourth to support transfer. Achievement Level 1 scholarship is for students who are eligible to enroll in Trigonometry or Pre-calculus at the time of the award and have three-years of study at Cañada College before transfer. Achievement Level 2 is for students who are registered in Calculus 1, or higher, at the time of the award, and are within two years of completing their Student Educational Plans (SEP) and transferring. Achievement Level 3 is for students who are within a year of completing their lower-division study at Cañada. The Transfer scholarship is for students who have completed all coursework included in their educational plan and are transferring at the time of the award. Table 2 shows the number of awards for each achievement level.

		Number of S-STEM Awards			
Level	**Amount**	**Year 1**	**Year 2**	**Year 3**	**Year 4**
Achievement Level 1	$3,000	9	10	9	9
Achievement Level 2	$4,000	6	10	10	10
Achievement Level 3	$4,000	6	11	11	11
Transfer	$4,000	0	6	11	11
Total Number of Awards		21	37	41	41

Table 2: Summary of proposed amounts and numbers of awards.

The rationale for the size of the proposed M-SETS scholarship awards is based on an analysis done in May 2008 by Cañada College's Office of Financial Aid to understand the actual unmet financial need of several cohorts of MESA students.

Student Scholarship Applications and Awards

Table 3 is a summary of the results of Years 1 and 2 application cycles of Cañada's S-STEM scholarship program. For Year 1, 35 students applied, and 21 awards were given. For Year 2, 31 students applied, and 20 new awards were given. For both years, applications for scholarships were accepted during both the spring and fall semesters.

	Grant Period	
	Year 1	**Year 2**
Number of Applicants	35	31
Number of New Awards	21	20
% Successful Applicants	60.0%	64.5%
Number of Continuing Scholars	-	17
Total Number of Scholars	21	37

Table 3. Summary of Year 1 and Year 2 applications and awards.

Of the 21 scholars selected in fall 2009, 17 are currently active continuing scholars. Three left the program at the start of spring 2010 semester. Two of the students were disqualified due to poor academic performance, and one student left the program because his family relocated to another state. At the end of spring 2010, one student left the program due to illness. For fall 2010, 20 new awards are given bringing the total number of active scholars to 37.

Student Demographics

Table 4 is a comparison the demographics of NSF scholars for fall 2009 and fall 2010. From 2009 to 2010, the percentage of female scholars dropped slightly from 38.1% to 35.1%. The percentage of students from traditionally underrepresented ethnic groups (Hispanic, African American, American Indian, Alaskan Native, and Pacific Islander) stayed about the same, 57.1% for 2009 and 56.5% for 2010. Note that for both years, the percentage of the underrepresented students among the scholars is higher than the College's overall percentage of 46.3% for fall 2009. The percentage of first generation college student increased from 52.4% in 2009 to 59.5% in 2010. The percentage of students who are the first in their family to major in a STEM field also increased from fall 2009 to fall 2010.

	Fall 2009		Fall 2010	
Demographics	Number	%	Number	%
Gender				
Female	8	38.1%	13	35.1%
Male	13	61.9%	24	64.9%
Total	21		37	
Ethnicity				
Alaskan or Native A	0	0.0%	1	2.6%
African American	0	0.0%	1	2.6%
Asian	2	9.5%	6	15.4%
Caucasian	7	33.3%	7	17.9%
Hispanic	12	57.1%	20	51.3%
Other/No Response	0	0.0%	4	10.3%
First in Family to Attend College?				
Yes	11	52.4%	22	59.5%
No	10	47.6%	15	40.5%
First in Family to Study a STEM field?				
Yes	18	81.7%	32	86.5%
No	3	18.3%	5	13.5%

Table 4. Summary of student demographics of active NSF scholars in fall 2009 and fall 2010.

Student Academic Majors

Table 5 shows a summary of the distribution of the academic majors of NSF scholars. For both years, engineering majors account for more than 50% of the scholars. There are a number of factors that may have contributed to this strong representation of engineering majors in the program. The Program PI is the head of the Head of the Engineering Department, and is heavily involved in recruitment. The College has a very strong Math, Engineering, and Science Achievement (MESA) program, and many of the program's activities are related to engineering. As a result, some of the most active MESA students are engineering majors, and many of them are also heavily involved in campus student organizations. Additionally, the Engineering Department has recently been awarded federal grant funds aimed at strengthening its programs. This includes a Minority Science and Engineering Improvement Program (MSEIP) grant from the US Department of Education, an Innovations in Engineering Education, Curriculum, and Infrastructure (IEECI) grant from NSF, and a Curriculum Improvement Improvements Partnership Award for the Integration of Research (CIPAIR) grant. The Cañada College NSF S-

STEM program team recognizes the need to increase the representation of students from other disciplines, and plans to involve more faculty from these disciplines in future recruitment efforts. As an initial step, two new faculty mentors have been added to this year's team – one from mathematics, and one from biological sciences.

	Fall 2009		**Fall 2010**	
Major	**N**	**%**	**N**	**%**
Astronomy	1	4.8%	0	0.0%
Biology	3	14.3%	3	8.1%
Biological Sciences	1	4.8%	5	13.5%
Chemistry	1	4.8%	2	5.4%
Computer Science	2	9.5%	1	2.7%
Mathematics	1	4.8%	3	8.1%
Aerospace Engineering	2	9.5%	1	2.7%
Architectural Engineering	1	4.8%	0	0.0%
Bio Engineering	0	0.0%	3	8.1%
Chemical Engineering	1	4.8%	2	5.4%
Civil Engineering	3	14.3%	4	10.8%
Computer engineering	2	9.5%	1	2.7%
Electrical Engineering	0	0.0%	4	10.8%
Environmental Engineering	1	4.8%	0	0.0%
Mechanical Engineering	1	4.8%	7	18.9%
Engineering	1	4.8%	1	2.7%
Total	21		37	

Table 5. Summary of majors of study of active NSF scholars

Student GPA and Work Hours

Table 6 shows a summary of the average student Grade Point Average and the average number of hours of work per week for the first three award semesters of the scholarship program. The average GPA of students stayed about the same from fall 2009 to spring 2010, and increased in fall 2010. The average number of hours per week that students worked decreased from 10.52 to 9.38 as many of the students were able to reduce the hours that they needed to work as a result of the scholarship. Additionally, many of these students either quit their off-campus jobs or reduced the hours they worked and replaced them with on-campus jobs as tutors or student assistants. For fall 2010, for instance, 27 out of the 37 active scholars have STEM-related jobs on campus, working as math, science or engineering tutors, laboratory assistants, or student assistants. Due to the addition of 20 new scholars in fall 2010, the average number of hours of work increased to 9.7. It is anticipated that this number will decrease by spring 2011 as students are able to work fewer hours.

	Fall 2009	Spring 2010	Fall 2010
GPA	3.30	3.29	3.43
Hours	10.52	9.38	9.70

Table 6. Comparison of average student GPA and average weekly hours of work for Fall 2009, Spring 2010 and Fall 2010.

3. NSF S-STEM Activities

Cañada College's NSF S-STEM program was designed not only to provide financial assistance to its participants but also to develop a set of activities and a support infrastructure that will help maximize student retention and success. Two important variables that are commonly believed to strongly influence the retention of students are academic and social integration as articulated by Tinto's model of college student persistence/withdrawal based on these variables.[8,9] It is widely assumed that academic and social integration are more difficult to achieve in the community college setting because of the lack of time to participate in institutional activities that facilitate such integration.[10] To enhance opportunities for the creation of academic and social integration, an approach that is of increasing popularity in community colleges is the use of learning communities. Learning communities are small groups of students who take thematically linked classes that are often interdisciplinary in order to enhance academic and social integration of students, and strengthen their cognitive skills.[11]

In developing activities to support the academic, personal, and professional development of NSF scholars, this learning community model is adopted to provide opportunities for academic and social integration while taking advantage of existing programs and resources. These activities are supported through the College's MESA Program, and two U.S. Department of Education grants – the Minority Science and Engineering Improvement Program (MSEIP) and the Hispanic-Serving Institution College Cost Reduction and Access Act (HSI-CCRAA) grant.

Academic Support Services

Academic support services for NSF scholars include tutoring, Academic Excellence Workshops, and Study Groups for most courses in math, sciences and engineering. Many of the NSF scholars work as tutors and workshop facilitators for these courses.

Professional Meetings/Conferences

The following is a list of meetings and conferences in which NSF scholars have participated within the last year:

- 7th Annual Pacific Gas & Electric/MESA Student Leadership Conference, Berkeley, CA, Oct. 15-16

- 2010 SACNAS (Society for Advancing Chicanos and Native Americans in Science) and MAES (Mexican American Engineers & Scientists) National Conference, Anaheim, CA, Oct. 6-10
- 24-hour Hackathon – Facebook and Girls in Tech, Sept. 11-12
- University of California, Berkeley Biology Majors Fair, Sept 11
- 3rd Annual Community College Honors Research Symposium, UC Berkeley, May 1
- MESA Student Leadership Retreat at Happy Valley, Santa Cruz, CA, April 17 – 19
- American Chemical Society National Conference, San Francisco, CA, Mar. 21-22
- Society of Hispanic Professional Engineers (SHPE) Regional Leadership Conference, CalPoly San Luis Obispo, Feb. 26-28

Field Trips to Industry Sites and Universities

The following is a list of field trips attended by NSF scholars in the last year:

- UC Davis STEM Day, Nov. 7
- CalPoly San Luis Obispo Engineering Open house, Oct. 23
- Stanford Med School -- Pre-Med Leadership Workshop, Oct. 23
- SJSU Engineering Open House, Oct. 16
- SHPE Bomba Blast at Apple, Oct. 16
- UC Berkeley Engineering Tours for MESA Students, Oct. 15
- SF Society of Women Engineers – boat tour of Bay Bridge construction project, Oct 1
- SHPE Day @ SF Exploratorium, Sept. 25
- Inside Google: Diversity in Engineering & Technology, Sept 1
- Cal Day @ UC Berkeley, April 17
- SJSU Engineering Open House, April 17
- Genentech Tour: The Women in Science & Engineering (WISE) club, Feb. 25

Workshops/Seminars

- NSF Scholars' Orientation, Nov. 12
- Guaranteed 4.0 Workshop, Nov 8 and Nov 11
- Writing Personal Statements for Transfer Applications or Scholarships, Oct. 14
- Transfer Application Help – UC, CSU & Private Universities, Oct. 13
- Women in Science & Engineering Speaker: A post-doctoral researcher in organic chemistry, Oct. 4
- Transfer Agreement Guarantee (TAG) Workshop, Sept. 22, Sept 1, August 24
- Student Panel – Student to Student: Experiences in Summer Internships, Sept. 9
- Industry Speaker – Career Path from MESA to a Job! A professional Civil Engineer who works as a Transportation Engineer for the City of Menlo Park and also owns a consulting company, Sept. 2
- Financial Aid – FAFSA Help – every Tuesday the Financial Aid Office helps students complete Free Application for Federal Student Aid (FAFSA), Weekly
- The Guaranteed 4.0 Workshop, Mar. 21-22

- Speaker Panel: Women in Engineering & Science: Meet 6 scientists and engineers from a variety of backgrounds and careers, March 25
- Speaker: Careers in Genetics Counseling. Speaker from Stanford's Master's Degree program in Genetics Counseling, March 24, Nov. 23
- MESA Math Challenge: Tackle 20 math questions in 60 minutes, March 17
- Scholarship Workshop: Spring Scholarships - find out what makes a successful application, March 9
- Guest Speaker from CALTRANS (also SFSU Faculty). He will talk about opportunities for Community College Students at CALTRANS, March 4
- Student-to-Student: What is an Internship Really Like? MESA Students will share their experiences in applying for and participating in research internships, Feb. 8
- Stanford's Women in Engineering Seminars: "Real Lives Have Curves," every Thursday, Jan. 26-March 11
- Student-to-Student: Experiences as a Transfer Student at UC Berkeley, Nov. 23

The following is a more detailed description of two of the workshops developed by Cañada College's STEM Retention Specialist.

Guaranteed 4.0 Workshop

Meeting the learning needs of underserved student populations at two-year postsecondary institutions often requires providing academic and personal support for this student cohort, as well as opportunities to develop the study skills necessary for college success. As part of that effort, a pilot program based on the "Guaranteed 4.0 Learning System[7]" was offered in the Spring Semester of 2010 for 27 students; in particular, the three-day study skills workshop combined study methods with stress and time management techniques to provide an overall framework for academic success. The Guaranteed 4.0 method has been taught at community colleges and Baccalaureate institutions nationwide, including University of California, at Berkeley, Stanford University, Northwestern University, Purdue University, University of Wisconsin, and Massachusetts Institute of Technology.

The core emphasis of the curriculum involved equipping students with strategies for classroom success: active listening skills during classroom instruction; self-efficacy and self-advocacy skills for working with college professors; and a note-taking system for classroom lecture, assigned reading and problem sets, and exams based on pre-conditions, repetition, and effecting information input. The pilot program not only included structured DVD viewings of actual Guaranteed 4.0 Learning System college seminars, but it also consisted of a variety of non-traditional elements in order to reinforce concepts introduced by the Guaranteed 4.0 method, such as a guided imagery and progressive relaxation exercise, a Vision Board activity, short classroom quizzes after each DVD chapter, and a pair-share exercise enabling participants to practice the Bullet Point method.

On Day One, students learned stress and time management techniques along with insight for maximizing learning opportunities through professors' office hours. Workbooks and thumb drives containing learning materials were distributed amongst the participants. The students were administered a pre-survey to self-assess their individual study skills that required improvement, and the majority of students highlighted time management as a major concern; for example, in the pre-survey, 25% had indicated they spent more than 25 hours studying per week and wanted a more efficient way to study. To create a safe space for discussion, the workshop instructor synthesized those concerns with the strategies and insights found in the Guaranteed 4.0 curriculum.

On Day Two, students were required to create a "Plan for a Success" whereby they identified which courses to study for at specific times and locations using a MS Excel template. Day 2 also included lessons on Bullet Point Reading, Lecture Notes, Homework and Exams. Finally, students were then organized into dyads, given assigned reading, and instructed to apply the Bullet Point method after reading short passages; participants were encouraged to share their learning experiences with their partners, and then share their thoughts and concerns with the entire classroom. The instructor answered their questions based on the DVD curriculum, and encouraged students to continue practicing the Bullet Point method at home.

On Day Three, occurring one week after Days One and Two, the instructor organized one final classroom meeting to follow-up with students, identifying successful experiences as well as challenges and shared frustrations. A student leader was pre-selected to share his experiences using the method in his transferable math and science coursework with the other participants, in addition to his detailed Bullet Point notes, as part of an effort to bolster student self-efficacy with respect to developing new study skills. Finally, students shared their Vision Boards, a collection of images representing their personal and work values and life goals, to foster a sense of community as well as to illustrate the connection between their self-understanding and the study skills workshop. Participants were then administered a post-survey and given a list of additional campus resources (e.g. free tutorial, academic counseling).

Among the participant responses, 65% found the Plan for Success exercise to be very useful, and 70% found the DVD to be engaging. In the future, instructors might consider giving students more time to practice the Bullet Point method since many participants had indicated they needed more than one hour to practice the method within a supportive learning environment.

NSF Student Orientation

The three-hour event offers students the chance not only to meet with each other and develop a sense of community, but it also provides students with information to help them formulate accurate expectations for maintaining scholarship eligibility and working with their assigned mentors. The orientation begins by reviewing the student contract, a document students have signed before accepting the award, which highlights academic responsibilities students must keep in order to maintain their eligibility for the award. Orientation also consists of a variety of activities designed to promote community: a family photo sharing exercise that connects their personal experiences to the NSF community; group discussions around the meaningful teachers and/or mentors; and a chance to write a letter to their mentors that expresses their hopes, goals, and concerns as NSF Scholars. Finally, the orientation provides instruction for cultivating mentors in college and the workplace, helping to shape student expectations and prepare them with the skills to locate support for academic and professional development.

Outreach Activities

The following is a list of outreach activities in which NSF scholars were involved:

- Cañada College's Annual High School Engineering Design Competition, Trebuchet Design Contest, April 23
- Science and Engineering Awareness Day, March 17
- Family Science Night at Hoover School in Redwood City. Volunteer to help inspire young kids about Science and Engineering. This is a project jointly sponsored by SHPE and San Francisco Exploratorium, March 4.
- Citizen School Robotics Celebration. Come see what Redwood City middle school students have done under the inspiration of Canada Robotics Club members, Dec. 7.
- Robotics workshops for middle and high school girls participating in the Girls Engaged in Math and Science (GEMS) Program.

STEM-Related Clubs

NSF Scholars have assumed leadership positions in the following STEM-related student organizations:

- Society of Hispanic Professional Engineers
- Women in Science and Engineering
- Pre-Med/Pre-Health Club
- Robotics Club
- Science Outreach Club

NSF Scholars Mentoring Program

As a major component of the Cañada College's NSF S-STEM program student support infrastructure, a mentoring program has been developed and implemented. For the first group of 21 scholars, six faculty members were selected and assigned mentees based on their specific disciplines. For the current group of 37 scholars, seven Science and Technology Division faculty members have been selected as mentors. Faculty mentors were selected from the following academic areas: Biological Sciences (2), Chemistry (1), Engineering (2), Engineering and Computer Science (1), and Mathematics (1).

Students and mentors are paired based on academic disciplines. The scholars and their mentors meet as a group through a mentoring lunch at least once every semester. At the fall mentoring kick-off luncheon, new scholars are introduced, and students and mentors are given an orientation to the mentoring program, as well as the benefits of the program, and the expectations and responsibilities of scholars. Mentors are expected to meet with their mentees either individually or in groups throughout the semester to develop and review Student Educational Plans, to discuss academic progress and problem areas, to help devise strategies to improve student performance in their classes, to help students get connected with resources, to provide career counseling, and to help students in completing applications for transfer to a four-year university, as well as applying for scholarships and internships. At the end of each school year, students are asked to evaluate their faculty mentor to assess the mentor's ability to help them with their educational and career endeavors as well as to rate the mentor's accessibility.

Transferring students are interviewed in depth about how the program has impacted their academic and professional development.

4. Student Involvement in Program Activities

This section summarizes the results of the implementation the program undertaken during the first two years of Cañada College's NSF S-STEM program. Table 7 summarizes the participation level of students in the various program activities designed to keep them engaged. Academic support services include the Math Lab, tutoring, MESA study groups and faculty office hours in the MESA Center. On-campus workshops include resume writing, applying for scholarships, applying for internships, writing personal statements, applying for transfer, financial planning, time management, the Guaranteed 4.0 workshop, and others that are specific to particular majors.

	Number of Students Involved	
ACTIVITIES	2009 (out of 21 students)	2010 (out of 37 students)
Academic support services	21	37
Career counseling	21	37
Community building	18	29
Field trips	12	21
Internships	1	6
Meetings/conferences	14	16
Mentoring	21	37
Recruitment	15	17
Research opportunities	2	4
Seminars	5	26
STEM-related campus employment	11	22

Table 7. Summary of student involvement in program activities

To evaluate the success and effectiveness of program activities, student surveys are conducted throughout the year. Additionally, more in-depth exit interviews with transferring students are conducted at the end of each academic year. Table 8 shows a summary of student responses to the 2009-2010 year-end survey. As the table shows, student perception of the usefulness of the activities are overwhelmingly positive, with mean responses between "Useful" and "Very Useful," except for Outreach Activities. The program activity that students found to be most useful is the mentoring program.

How Useful are the following activities?

1 – Not useful at all; 2 – Somewhat useful; 3 – Useful; 4 – Very Useful	
ACTIVITIES	**Average Response**
Academic support services	3.45
Meetings/conferences	3.50
Field trips	3.50
Workshops/seminars	3.17
Outreach activities	2.82
STEM-related clubs	3.18
Mentoring	3.71

Table 8. Summary of student perception of usefulness of program activities determined from 17 respondents to the Spring 2010 end-of-semester survey.

Table 9 is a summary of student opinion of the usefulness of some of the events that were held over the past year. Students found all of the events useful, with all average ratings between "Useful" and "Very Useful." The results of these student surveys are used to determine which events to develop further in the future.

How Useful are the following events? 1 – Not useful at all; 2 – Somewhat useful; 3 – Useful; 4 – Very Useful	
EVENT	**Average Response**
Pre-Med & Public Health Conference	3.33
MESA field trip CalPoly Engineering	3.80
PG&E/MESA Student Leadership Conference	3.83
Engineering & Science Awareness Day	3.40
Touring Apple Co.	4.00
SHPE Regional Leadership Conference	4.00
MESA Student Leadership Retreat @ Happy Valley	3.50
MESA Math Challenge	3.50
Lynn Belingheri & Transfer Admission Guarantee (TAGs)	3.82
The Guaranteed 4.0 Workshop	3.73
American Chemical Society National Conference	3.67
MESA Alumni panel	3.75
Genetic Counseling Workshop	4.00

Table 9. Summary of student perception of usefulness of program events.

5. Student Self-Reported Impact on Personal Efficacy

The following is a summary of student-reported impact of receiving a scholarship on their personal efficacy.

- Winning the scholarship encouraged me to keep going and it boosted my confidence.
- Winning a Scholarship showed me that I'm doing well at school and I should keep it up to get more scholarships.
- My confidence was greatly increased. I have always felt that scholarships were reserved for godly students, but I know now that anything is achievable.
- Winning the scholarship showed me that there is help and support to achieve my goals
- I was able to set in my mind that achieving my academic goal not only had to do with doing well in classes but also with building a supportive community where everyone was enthusiastic and eager to learn and that's why I maintained my participation with the Society of Hispanic Professional Engineers, the American Chemical Society (ACS) and Phi Theta Kappa, organizations that provided different venues and resources to explore my interests.
- It was the first scholarship I applied for and once I got that one, it gave me confidence that I don't have to be a 4.0 student to actually get money....although being a 4.0 won't hurt.
- Receiving this scholarship has aided in my confidence when it comes to applying for other scholarships
- It impacted my confidence a lot by helping me to feel supported in my pursuit towards my academic goals as well as to know that there are people who care about my education.
- With the NSF scholarships consistent checks each semester, I feel confident that I can spend more time on my school work then I could have if I had not received it. It gives me confidence in having enough time to get the grades that I need to get into the schools that I am interested in. Also, it reminds me that people are there supporting my goals.
- It has given me confidence and encouragement in continuing my goals and also drives me to keep improving.
- Winning this scholarship gave me a lot more confidence in myself.
- The NSF scholarship empowered me to dream big, because I knew that there are people like in the NSF that want to help students.
- The NSF scholarship has given me the confidence that I can achieve anything.
- This scholarship means a whole lot to me. This is the driving force I need to motivate myself to continue and to pursue my dream as a chemical engineer
- It has encouraged me more to work harder.

6. Conclusion

The first two years of implementation of Cañada College's NSF S-STEM program show success in achieving the primary program goals of providing an opportunity for low-income students to focus on their studies and fully benefit from a student support infrastructure that promotes academic excellence, leadership skills, and professional and personal growth among students. The success of the program thus far may be partly attributed to a well planned set of activities designed to create a learning community among scholars. Participation among scholars in these program activities has been high, and most of the activities were perceived by participants to be valuable, with the mentoring program being rated by students as the most useful activity. Crucial to the success of the program are strong collaborative relationships among program personnel that include the MESA Director, Financial Aid Office personnel, academic counselors, and faculty mentors from the main STEM disciplines. Successful implementation of program activities also involved alumni, student organizations, and partners from industry, four-year institutions, local high schools, and professional organizations. The program has also leveraged resources from the College's strong MESA Program, as well as two student support programs funded by the US Department of Education – the Minority Science and Engineering Program (MSEIP), and Hispanic-Serving Institution College Cost Reduction and Access Act (HSI-CCRAA) grant.

Among the program focus areas for the next year include greater involvement of students in paid STEM-related internships, integration of service-learning components in program activities, and development of more targeted recruitment strategies to attract more incoming freshmen students from underrepresented groups. Another area of focus is sustaining program activities to support student success beyond the duration of the grant.

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Biographical Information

Amelito Enriquez is a professor of engineering and mathematics at Cañada College. He received his PhD in Mechanical Engineering from the University of California, Irvine. His research interests include technology-enhanced instruction and increasing the representation of female, minority and other underrepresented groups in mathematics, science and engineering.

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Strengthening the STEM Pipeline through an Intensive Review Program for Math Placement Testing

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Abstract:

Although many California Community College students from underrepresented groups enter college with high levels of interest in science and engineering, their levels of preparation for college-level work, especially in math and engineering, are so low on average that the majority of them drop out or change majors even before taking transfer-level courses. To facilitate the transition of these students into transfer-level math, science, and engineering courses, Cañada College, a federally designated Hispanic-serving institution in the San Francisco Bay Area, developed an intensive math placement test review program. The Summer Math Jam is a two-week intensive mathematics program designed to improve students' preparation for college-level math courses. Implementation of the program over the last two years shows success in improving student performance in the math placement test, and success in creating a sense of community among program participants. An analysis of student academic performance in subsequent semesters show significantly higher success and retention rates among Math Jam participants compared to nonparticipants. Since the implementation of Math Jam, enrollments in STEM courses have increased significantly, with a higher rate of increase among minority students. The success of Math Jam in improving the participation, retention, and success of minority STEM students has led to the development of the Mini-Math Jam – a shorter, one-week version of Math Jam that is offered a week prior to the beginning of the fall semester, and during the winter break. The Mini-Math Jam has also been successful in helping students improve their placement scores, and preparing them for subsequent math courses they take.

1. Introduction

Community colleges serve as the gateway to higher education for large numbers of students in the U.S., especially minority and low-income students. Yet for many students, the community college gateway does not lead to success. According to a study of community colleges in California, only one in four students wanting to transfer or earn a degree/certificate did so within six years.[1] The completion rates for African American and Hispanic students are even lower, with only 15% of African American students and 18% of Latino students completing a degree or certificate within six years, compared to 27% of Caucasian students, and 33% of Asian students.

For Science, Technology, Engineering, and Math (STEM) fields, lower success and retention rates for minority students are observed at both community college and university levels resulting in underrepresentation of minority groups in these professions. For instance, while comprising almost 25% of the U.S. population, African Americans and Latinos make up less than 7% of the individuals with B.S. or higher-degrees in the science and engineering fields.[2] Strategies that have been proven effective in increasing the retention and success of minority students in science and engineering include mentoring programs,[3,4] introducing context in introductory courses,[5] alternative instructional strategies such as collaborative and interactive learning,[6] and summer bridge programs.[7,8]

In 2008, Cañada College, a Hispanic-Serving community college in Redwood City, CA, was awarded a Minority Science and Engineering Improvement Program (MSEIP) grant by the US Department of Education. The project, entitled Student On-ramp Leading to Engineering and Sciences (SOLES), aims to increase the participation, retention, and success of underrepresented and educationally disadvantaged students interested in pursuing careers in STEM fields. Among the strategies developed for this project is the Summer Math Jam – a two-week intensive mathematics program designed to improve students' preparation for college-level math courses. This paper summarizes the results of the implementation of the Math Jam and its one-week version, the Mini-Math Jam, over the last two years.

2. Incoming Student Interest and Level of Preparation for Engineering

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 (SMCCCD). It is one of only two federally-designated Hispanic Serving Institutions in the San Francisco Bay Area. The College opened in 1968, and is located in Redwood City, California. During the 2009-2010 academic year, the College enrolled 11,566 students. The student body is genuinely multi-cultural with Hispanic students as the largest single group at 39.2%; white students comprise 33.3%, Asians 8.6%, African-Americans 3.8%, Filipinos 3.6%, Pacific Islanders 1.7%, American Indian/Alaska Natives 0.4%, other 9.5%.[9] Like all of the California Community College System institutions, Cañada is an open-enrollment institution, designed to welcome students of all ages and backgrounds to higher education.

Students Who:	Pre-algebra	Algebra	College Algebra	Trigonometry
Took the Math placement Test	47.1%	28.0%	17.0%	7.9%
Declared majors in STEM fields	32.9%	26.7%	23.8%	16.6%
Declared majors in Engineering	20.7%	32.0%	27.2%	20.1%

Table 1. Summary of April 2006 to April 2010 Math Placement Test results for 6300 students of all majors, 697 students who declared STEM majors, and 169 students who declared engineering majors.

At Cañada College, an important factor that contributes to low degree completion and transfer rates for STEM majors can be attributed to the inadequate preparation of community college students to take college-level mathematics courses. Table 1 summarizes the Math Placement test results of Cañada College students from April 2006 to April 2010. Among all students who took the placement test, 75.1% placed into either pre-algebra or algebra. For students who declared a STEM major, the results were only slightly better, with 59.6% of students placing into either pre-algebra or algebra. Even among those who declared engineering as their major, over 50% of students placed into one of these two remedial math courses. The results of these math placement tests have serious and adverse consequences for these students' timely completion of lower-division courses, and subsequent transfer to a university.

The performance on the math placement test is correlated with student ethnicities. Table 2 summarizes the ethnic distribution of the math placement test results for students who declared a STEM major. Among the biggest ethnic groups, African American students have the lowest percentages of students placing into trigonometry (6.3%), and the highest percentages of students placing into pre-algebra (71.9%), followed by Mexican Americans with 12.5% placing into trigonometry, and 39.1% placing into pre-algebra.

Ethnic Group	Pre-algebra	Algebra	College Algebra	Trigonometry	% of Total
African American	71.9%	15.6%	6.3%	6.3%	4.6%
Asian American	20.8%	22.9%	33.3%	22.9%	6.9%
Caucasian	22.9%	31.4%	24.8%	21.0%	30.1%
Mexican American	39.1%	26.2%	22.1%	12.5%	38.9%
Other	30.9%	24.3%	26.5%	18.4%	19.5%
All Ethnicities	32.9%	26.7%	23.8%	16.6%	100.0%

Table 2. Ethnic distribution of Math Placement test results for students who declared majors in STEM (Data from April 2006-April 2010; 697 students).

Although nationally, interest in science and engineering is lower for Latino, African American, and Native American students compared to other ethnic groups,[10] this is not the case at Cañada College. Table 3 summarizes the percentages of students taking the placement test, students declaring STEM majors, students declaring an engineering major, and students who transferred to a four-year school as an engineering major (2006-2010) for the four largest ethnic groups – Mexican Americans, Caucasian, Asian Americans, and African Americans. Although Mexican Americans represent only 37.2% of all the students who took the placement test, they represent 38.9% of students who declared a STEM major, and 46.2% of students who declared engineering as their major. Despite such a high interest in engineering among Mexican Americans, they represented only 19.4% of all students who transferred to a four-year school as engineering majors from 2006-2010. These data clearly represent a much lower rate of retention and transfer for Mexican Americans compared to Caucasian and Asian Americans.

The first two years of typical engineering curricula require two years of courses that include sequences of courses in calculus and physics. A student who starts at College Algebra has an additional one and a half years of mathematics (College Algebra, Trigonometry and Pre-calculus) on top of the two-year sequence of lower-division transferable courses. A student who starts at Pre-algebra has an additional two and a half years (Pre-algebra, Algebra, College Algebra, Trigonometry and Pre-calculus) of mathematics before they are ready to take Calculus. Hence, 39.1% of Mexican Americans and 71.9% of African American students will need at least four years at Cañada College before transferring. For many of them with family obligations and no family support, this is simply too long of a career path.

Percentage of Students Who:	**Mexican American**	**Caucasian American**	**Asian American**	**African American**	**Other**
Took the Math placement Test	37.2%	30.2%	5.7%	6.4%	20.5%
Declared majors in STEM fields	38.9%	30.1%	6.9%	4.6%	19.5%
Declared majors in Engineering	46.2%	27.8%	4.1%	3.6%	18.3%
Transferred as Engineering majors	19.4%	21.3%	30.6%	0.9%	27.8%

Table 3. Summary of the ethnic distribution of Cañada College students who took the placement test (April 2006-April 2010; 6,300 students), who declared STEM majors (697 students), who declared majors in engineering (169 students), and who transferred to a four-year school as engineering majors (2006-2010, 108 students) for the four largest ethnic groups.

3. The Summer Math Jam

The Summer Math Jam at Cañada College was developed to help students who have expressed interest in pursuing engineering and other STEM majors but placed low in the sequence of math courses.

The Summer Math Jam was developed with the following program goals:

1. Help students progress faster through Cañada's math sequence to enable them to transfer to a 4-year university earlier or to complete an associate's degree earlier.
2. Increase students' awareness of the tools, skills, and resources they need to be successful college students.
3. Develop a community of learners among program participants.

Both the 2009 and the 2010 Summer Math Jams were held from 9:00 a.m. to 3:00 p.m., Monday through Thursday during a two-week period that coincided with Cañada College's break between the end of spring semester and the beginning of the summer term. Morning and afternoon sessions were devoted to studying math either in groups or individually using MyMathTest,[11] an online system developed by Pearson Education for developing math placement tests and short math refresher programs. Workshops related to resources and skills needed for college success were offered in the afternoon. As a result of a mid-program focus group that indicated that students wanted to devote more time to studying math, and less on these workshops, the afternoon college success workshops were made optional for the second week of the 2009 Math Jam and the entire 2010 Math Jam.

Table 4 summarizes the demographics of Math Jam participants in the last two years. The number of participants more than doubled, from 50 in 2009 to 129 in 2010. For both years, a majority of participants were female, with Hispanic being the predominant ethnic group. In 2009, 50% of the participants were the first in their family to attend college compared to 42.9% for 2010.

Demographics	**2009**	**2010**
Number of Participants	50	129
Gender		
Female	64.7%	55.9%
Male	35.3%	44.1%
Ethnicity		
African American	5.9%	3.6%
Asian/Pacific Islander	2.9%	10.7%
Caucasian	20.6%	24.1%
Hispanic	61.8%	58.0%
Native American/Alaskan Native	0.0%	1.8%
Other	8.8%	7.1%
First in Family to Attend College?		
Yes	50.0%	42.9%
No	50.0%	57.1%

Table 4. Demographics of Summer Math Jam participants.

Table 5 is a summary of the results of the last two years of implementation of Math Jam. Even though the number of participants more than doubled from 50 in 2009 to 129 in 2010, the completion rates remained about the same, 84% for 2009, and 83% for 2010. Among students who have pre- and post-program placement test scores, the percentage of students with higher post-program scores decreased slightly from 94% in 2009 to 91% in 2010. However, the percentage of students who placed into at least the next higher math level after Math Jam increased from 64% in 2009 to 71% in 2010. These results are significantly better than the 56% "jump rate" for participants of a similar two-week summer math bridge program at Pasadena City College.[12]

Summer Math Jam Results	2009 Math Jam	2010 Math Jam
Number of Participants	50	129
Number Completed	42	107
Completion Rate	84%	83%
With Pre- and Post-Test Scores	33	42
Improved Test Scores	94%	91%
% Placed into Higher Level	64%	71%

Table 5. Summary of Math Jam results in 2009 and 2010.

Question	Pre-Program	Post-Program	Difference (Post - Pre)
How would you rate your math study skills? 1=poor, 5=excellent	3.064	3.635	0.571***
How would you rate your confidence in math? 1=not at all confident, 5=very confident	3.155	3.619	0.463**
How effective are you at time management? 1=not at all effective, 5=very effective	3.698	3.813	0.114
To what extent do you feel that you have supportive relationships with students at Cañada? 1=not at all supportive, 5=very supportive	3.766	4.127	0.361*
To what extent do you feel that you have supportive relationships with tutors at Cañada? 1=not at all supportive, 5=very supportive	3.657	4.377	0.720***
How interested are you in studying STEM? 1=not at all interested, 5=very interested	3.778	3.825	0.047

* The difference is statistically significant ($p < 0.050$).
** The difference is statistically significant ($p < 0.010$).
*** The difference is statistically significant ($p < 0.001$).

Table 6. 2010 Math Jam Student Survey Results.

To evaluate the success of Math Jam in achieving its secondary goals of increasing student awareness of tools, skills and resources needed to succeed in college, pre- and post-program student surveys were administered. Table 6 summarizes student responses to the pre- and post-program surveys. Statistically significant improvements were observed in the following areas: student rating of their math study skills, student rating of confidence in math, and student perceived supportive relationships with other students, and tutors. The improvement in student perception of effectiveness in time management, and the increase in their interest in studying STEM are not statistically significant.

4. Academic Performance of Math Jam Students

To truly evaluate the success of the Math Jam program in helping students achieve their academic goals, the success of the program participants beyond the two-week duration of the program needs to be monitored. To this end, the performance of the 2009 Math Jam participants in the math courses they took in fall 2009 was monitored. Table 7 is a comparison of the performance of three groups of students: 2009 Math Jam students who advanced at least to the next math class during math jam, 2009 MJ students who did not advance to the next math class during the program, and all students in fall 2009 math courses. The performance measures compared are the retention rate and success rates in the math courses. The last two columns of Table 7 show that 2009 Math Jam students when taken as a group have higher retention and success rates (75.7% and 62.2%, respectively) compared to all math students in the semester (74.5% and 50.5%, respectively). The third column of Table 7 shows that despite having already skipped at least one math class, the MJ students who advanced significantly outperformed all the math students in the semester, with much higher retention rate (84.2% versus 74.5%), and success rate (68.4% versus 50.5%). This is a significant result that addresses some initial concern among math faculty that skipping a math course might result in students being less prepared to be successful in the more advanced math course.

	MJ Students who Advanced (N=19)	MJ Students who did not Advance (N=18)	All MJ Students (N=37)	All Math Students (N=1515)
Retention Rate	84.2%	66.7%	75.7%	74.5%
Success Rate	68.4%	55.6%	62.2%	50.5%

Table 7. Performance of 2009 Math Jam students in fall 2009 math courses.

One of the primary reasons for the low degree-completion and transfer rates among community college students is the low persistence rates, i.e., students not continuing from one term to the next.[13] Another indication of better performance of 2009 Math Jam participants is their persistence from one semester to the next. Table 8 is a comparison of the persistence rates of Cañada students and 2009 Math Jam participants. Over the last several years, a study of first time fall semester Cañada students shows persistence rates of 55% for the following spring semester, 38% for the fall of the following year and 32% for the spring semester of the second year. For the 2009 Math Jam participants, the corresponding persistence rates were 93% for spring 2010, and 76% for fall 2010. At the time of writing this paper, the spring 2011 enrollments had not been completed. With much higher persistence rates, the degree-completion and transfer rates for these students are expected to be much higher as well.

Two important variables that are commonly believed to strongly influence the retention of students are academic and social integration as articulated by Tinto's model of college student persistence/withdrawal based on these variables.[14,15] It is often assumed that academic and social integration are more difficult to achieve in the community college setting because of the lack of time to participate in institutional activities that facilitate such integration.[16] To enhance opportunities for the creation of academic and social integration, an approach that is of increasing popularity in community colleges is the use of learning communities. Learning communities are small groups of students who take thematically linked classes that are often interdisciplinary in order to enhance academic and social integration of students, and strengthen their cognitive skills.[17] There are many studies showing that learning communities can significantly increase student retention, especially in developmental courses.[17,18,19,20,21,22]

	All First Time Students	2009 Math Jam Attendees
Fall of Yr 1	100%	100%
Spring of Yr 1	55%	93%
Fall of Yr2	38%	76%
Spring of Yr 2	32%	?

Table 8. Comparison of persistence rates of all first time Cañada students and 2009 Math Jam participants.

The success of Math Jam in increasing the retention rate among its participants may be analyzed in framework of Tinto's academic and social integration model. The intense two-week, 6 hours per day format of Math Jam provides an ideal context for academic and social integration among its participants, and may prove to be as effective as semester- or year-long learning communities programs that are commonly adopted in community colleges to improve student retention. Math Jam's informal instructional format of individual and group study sessions creates a relaxed and supportive learning environment. Additional opportunities for social/non-academic interactions arise during snack and lunch breaks, and during optional afternoon workshops that explore students' strengths and weaknesses, as well as skills, resources and attributes important for college success. This creates a sense of integration and connectedness that is evident in the results of participant responses to the pre- and post-program surveys – statistically significant increases to student perceived supportive relationships with Math Jam tutors, and with other participants.

5. Mini-Math Jam

Because of the success of the summer Math Jam, and student demand for it, Cañada College decided to offer Mini-Math Jam sessions. Mini-Math Jam is a one-week version of Math Jam offered a week before the beginning of the semester, and is designed to help students prepare for taking a math class during the semester. It was offered once in January 2010, the 2010 Winter Mini-Math Jam, and in August 2010, the 2010 Summer Mini-Math Jam, and the results are summarized in Table 9. The completion rates for the two MMJ sessions are comparable, 87% for the winter, and 91% for the summer session. However, the percentage of students who placed into higher math class is much lower for the winter MMJ than the summer MMJ. This is because most of the students for the winter MMJ are not first time students who are trying to improve their initial math placement results but are returning or continuing students whose primary purpose in attending the MMJ is to prepare for the math courses that they are taking the following spring semester. At the time of writing this paper, another MMJ is scheduled for January 10-14, 2011, and student interest continues to rise, as more than 130 students have applied to participate.

Mini-Math Jam Results	2010 Winter MMJ	2010 Summer MMJ
Number of Participants	87	74
Number Completed	76	67
Completion Rate	87%	91%
With Pre- and Post- Test Scores	22	31
% Placed into Higher Level	36%	61%

Table 9. Summary of the results for the 2010 winter and 2010 summer mini-Math Jam.

6. Effect on STEM Enrollment

The primary goal of the US Department of Education Minority Science and Engineering Improvement Program (MSEIP) grant that funds Math Jam is to increase the number of minority students majoring in science and engineering, and transferring to four-year institutions as STEM majors. To determining the success of math jam in achieving this goal, enrollment trends in transfer-level math, science, and engineering courses are analyzed.

	Minority		Non-Minority	
	Fall 2009	Fall 2010	Fall 2009	Fall 2010
Engineering	133.3%	200.0%	46.3%	80.5%
Mathematics	46.3%	46.3%	20.3%	9.3%
Biological Sciences	36.1%	28.6%	14.2%	27.9%
Chemistry	178.1%	90.6%	95.2%	74.6%
Physics	22.2%	55.6%	-12.5%	7.8%

Table 10. Comparison of percentage increase in enrollment in selected STEM areas for minority and non-minority students for fall 2009 and fall 2010. All percentage changes are with respect to the program base year of fall 2008.

The success of the Math Jam and Mini-Math Jam programs has contributed to significant enrollment increases in transfer-level courses in math, sciences and engineering. Table 10 shows the percentage increases in enrollment in STEM courses among minority and non-minority students. Since fall 2008, the base year of the Math Jam program, enrollments in transfer-level courses in math, engineering, biological and physical sciences have increased significantly. The percentage increase in the number of minority students enrolled in these courses is significantly higher than the percentage increase for the non-minority groups. The biggest differences in rates of increase between minority and non-minority student enrollments are observed in engineering (200% for minority students vs. 80.5% for non-minority students), mathematics (46.3% for minority students vs. 9.3% for non-minority students), and physics (55.6% for minority students vs. 7.8% for non-minority students). It should be noted that among the STEM areas, engineering, math and physics courses have higher prerequisite math courses beyond College Algebra. Enrollment in transfer-level courses in these subject areas is highly dependent on timely completion of the required sequence of math courses, a direct effect of successful participation in Math Jam. Over the same period, overall college enrollment increased by 8.4%, significantly lower than the increase for transfer-level STEM courses.

7. Conclusion

The first two years of implementation of Math Jam have been successful in achieving the program's primary goal of helping students progress faster through Cañada's math sequence. A majority of students who have pre- and post-program math placement test scores placed into at least the next higher math course. This results in a reduction of the cost and time for these students to complete their degrees and/or the lower-division courses they need to transfer to a four-year institution.

Math Jam has also been successful in increasing students' awareness of college success tools and skills, and in creating a community of learners that felt comfortable at Cañada. Academic performance of Math Jam participants in semesters following their participation in the program was significantly better both in the areas of retention and success rates, indicating the effectiveness of the program. Even more remarkable is the significantly higher persistence rate of Math Jam participants, with a one-year persistence rate that is double that of the College's rate among first-time students based on historical data. The improved persistence may be attributed to the enhanced academic and social integration experienced by Math Jam participants brought about by an intense and focused yet informal instructional atmosphere that fosters a sense of community among program participants, and a feeling of connectedness to the program staff and the College as a whole. These results indicate that shorter programs may be as effective as, or even more effective than traditional semester-long or year-long learning communities in creating opportunities for student engagement and immersion into the college experience in order to increase student persistence.

Math Jam was designed primarily to help students who have expressed interest in a STEM field but have low levels of preparation for taking college-level math courses as indicated by their math placement test results. Due to high interests in STEM and low placement test scores, participation in the program was higher among minority students compared to non-minority students. This higher rate of participation among minority students and the success of Math Jam in enhancing their academic performance are reflected in the increase in enrollment in transfer-level STEM courses since the program was initiated. Although enrollments in STEM transfer-level courses have increased for all student groups and for all STEM areas, the rates of increase are significantly higher among minority students, especially for engineering, mathematics, and physics where minority student enrollment has traditionally been lower due to inadequate high school preparation in math.

The success of Math Jam has prompted Cañada College to institutionalize the program. Beyond the duration of the three-year Minority Science and Engineering Improvement Program grant that funds the Math Jam, the College will continue to implement and improve the program and contribute to the strengthening of the STEM educational pipeline for students from underrepresented groups. As more students choose the community college pathway towards careers in science, technology, engineering, and mathematics, more programs like Math Jam need to be developed in order to produce the well-educated work force that is needed to ensure that the United States remains the premier place in the world for innovation.

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Transforming Engineering Education through Innovation and Entrepreneurship Program at MUSE

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Abstract

A self-sustaining Center for Innovation and Entrepreneurship (CIE) established at the Mercer University School of Engineering (MUSE) serves to promote and enhance cross-disciplinary educational programs (teaching, collaboration, and learning) as well as research and scholarly activities among Mercer faculty and students on innovation, creativity, and entrepreneurship. The School of Engineering, School of Medicine, School of Law, School of Business and Economics and College of Liberal Arts are involved in this program. The center focuses on fostering innovation and creativity among faculty and students thereby providing experience in the knowledge, skills, and attitude of the entrepreneurial mindset. This center supports the following: educational interdisciplinary curricula and co-curricular activities directly benefitting undergraduate, graduate, and professional students in all engineering specializations and programs in business, medical, and law schools; and individual and cross-disciplinary research initiatives designed to attract extramural funding. This paper highlights the innovation, invention, and creativity related skills and activities across Mercer campus, selected entrepreneurial design projects successfully completed, and hands-on course modules developed and implemented in the manufacturing related courses at MUSE. The results are presented and discussed.

1. Introduction

In recent years, the entrepreneurship education and research has focused a great deal of attention on opportunity recognition as a key aspect of research and practice[16]. The field of entrepreneurship has been defined as the "study of the sources of opportunities; the process of discovery, evaluation, and exploitation of opportunities"[18]. The entrepreneur has been described as "an innovator or developer who recognizes and seizes opportunities, converts these opportunities into workable and/or marketable ideas"[11].

Observations have been made on the changing role of universities in society[17]. The importance of entrepreneurship education has been emphasized in business and engineering schools. There is a growing need to enhance the entrepreneurship education in universities and colleges due to globalization and emerging international competitions [5, 10]. Entrepreneurship requires learning methods, pedagogical processes and frames for education[3]. Managing innovation, integrating technological, market, and organizational change have been studied by several authors and are being taught at business school[6, 21]. Design for manufacture and assembly and concurrent engineering concepts have been addressed in technology ventures and engineering entrepreneurship education [2, 4, 8].

In addition to the traditional roles of knowledge production and diffusion through research and teaching, universities have become more actively involved in the commercialization of knowledge[17]. Creation of academic ventures and business incubation has received increased attention lately [9, 14, 23]. Academic ventures are seen as important means for enhancing local economic development, generating income to support research, and encouraging inventor involvement[19].

With the changing role of universities, the role of academics has also changed. From being more likely to have the role of advisors, facilitating the transfer of knowledge to the new venture, they are today more likely to be members of the entrepreneurial team, thus playing greater role in identifying and developing the entrepreneurial opportunities, acquiring resources, and organizing the venture[17].

Entrepreneurial education must include skill building courses in negotiation, leadership, new product development, creative thinking and exposure to new technological innovation[12]. Technology must be embraced within the classrooms. Solomon, Duffy and Tarabishy[20] conducted one of the most comprehensive empirical analyses on entrepreneurship education. In their view of entrepreneurship pedagogy, they stated, "A core objective of entrepreneurship education is that it differentiates from typical business education. Clearly, for entrepreneurship education to embrace the 21st century, professors must become more competent in the use of academic technology and also expand their pedagogies to include new and innovative approaches to the teaching of entrepreneurship."

Since 2006 KEEN (Kern Entrepreneurship Education Network) colleges are preparing more entrepreneurial engineers in the United States[22]. There are 20 KEEN colleges that share the same vision to instill entrepreneurial mindset into engineering undergraduates. MUSE, one of the KEEN colleges, is closely working with nationally known centers for entrepreneurship education and other KEEN colleges to learn from their experiences and to establish the CIE to promote entrepreneurship education at Mercer campus.

2. Mercer Entrepreneurship Engineering Education Program (MEEEP)[15]

The purpose of Mercer University's School of Engineering is to educate a student who is prepared to be practicing engineer, one who can responsibly contribute to a global society that is becoming ever more dependent on technology. While the focus of the engineering school is to educate engineers, its graduates may enter many fields of graduate studies, especially those requiring the disciplined problem solving methods developed in the undergraduate curriculum. The engineering graduates have entered professional graduate programs in medicine, law, and business, as well as graduate engineering programs. There are 415 undergraduate and 135 graduate students at Mercer School of Engineering. The ABET accredited undergraduate program has biomedical, computer, electrical, environmental, industrial, and mechanical engineering specializations. There are 28 engineering faculty engaged in teaching undergraduate and graduate programs[13].

The entrepreneurship certificate program was established through Kern Family Foundation Grants in 2007. This program is open to all engineering students at MUSE. Students who complete the course requirements will receive a Certificate of Achievement in Engineering Entrepreneurship. The entrepreneurship certificate program requires completion of the following courses:

- MKT 361: Principles of Marketing
- MGT 363: Principles of Management
- MGT 427: Entrepreneurship
- EGR 482: Engineering Innovation and Creativity
- EGR 483: Entrepreneurship in Engineering Design

Note: EGR 482 must be taken with EGR 487: Engineering Design Exhibit I and EGR 483 must be taken with EGR 488: Engineering Design Exhibit II.

In addition to the above courses the engineering students are encouraged to take ECN 150: Principles of Microeconomics during their sophomore year. Table 1 shows the courses taken by semester to complete the certificate program in entrepreneurship. The catalog description of the entrepreneurship certificate program courses are found in Mercer University Catalog[13].

Table 1: Courses taken by semester

Sophomore-1	Sophomore-2	Junior-1	Junior-2	Senior-1	Senior-2
			EGR 480	EGR 487	EGR 488
			MGT 427	EGR 482	EGR 483
	(ECN 150)	MKT 361			
		MGT 363			

1: Fall semester; 2: Spring semester.

In addition to the certificate program courses, course modules on creativity, invention, innovation, and entrepreneurship have been developed and taught in the following freshman through senior level courses: EGR 107: Introduction to Engineering Design; MAE 205: Visualization and Graphics; EGR 245: Electrical Engineering Fundamentals; ISE 370: Manufacturing Processes; MAE 305L: Manufacturing Practices Lab; ISE 425: Computer Assisted Manufacturing Systems & Lab; ISE 429: Robotics; BME412: Biomechanics; and BME413: Advanced Biomechanics. The MEEEP courses and modules provide opportunities for all engineering students to be part of entrepreneurship program at MUSE.

Since 2007, all engineering students took one or more courses and/or modules listed in the entrepreneurship certificate program;15 entrepreneurial senior design projects were funded; 50 or more students participated in the business plan/entrepreneurial senior design project competitions; one of the projects received national and state recognition; five projects received regional/Mercer awards; more than 30 papers were presented in regional, national, and international conferences by faculty and students; students and faculty applied for 3 provisional patents and 1 utility patent; students and faculty are in the process of forming at least two startup companies focusing on low cost electromechanical and biomedical devices; and more than 20 students are working as intrapreneurs in major industries/corporations in Georgia and neighboring states. Students and faculty team are preparing to organize "Innovation Chase" competition among Mercer students during March 18-20, 2011.

3. Center for Innovation and Entrepreneurship (CIE)

In 2010, Mercer's Academic Initiatives Monetary Fund (AIM Fund) has approved the creation of the "Center for Innovation and Entrepreneurship" at MUSE, to enhance the activities of MEEEP across Mercer campus. The center is operating since August 2010. The CIE focuses on cross-disciplinary educational programs (teaching, collaboration, and learning) as well as research and scholarly activities among Mercer faculty and students. This unique center initially involves the School of Engineering, School of Medicine, School of Law, School of Business and Economics, and College of Liberal Arts. Possible future participation is envisioned from other colleges and schools such as College of Nursing, College of Pharmacy and Health Sciences, School of Theology, and School of Music. The CIE provides an interdisciplinary collaboration that is necessary for submitting competitive extramural funding proposals. It serves as a platform for diverse scholarly activities, curricular and co-curricular enhancements.

On August 20, 2010, the CIE and MEEEP organized a workshop for the entire engineering faculty on "entrepreneurial education through case studies." The workshop had sessions on (1) entrepreneurial thinking/entrepreneurial mindset (2) importance of entrepreneurship in engineering education (3) role of engineering faculty and faculty development and (4) team work on entrepreneurial thinking and case study. All 28 engineering faculty participated in the workshop.

During September 16-17, 2010, KEEN Regional Conference on Innovation and Entrepreneurship was hosted by the CIE and MEEEP at the Mercer University School of Engineering. The overall objective of the conference was to bring together faculty and students from KEEN schools on a common platform and discuss about the progress made in each KEEN school in the areas of invention, innovation and entrepreneurship through faculty and student presentations and promote future collaboration among participating KEEN schools: (1) initiate collaboration in teaching, senior design projects, and exchange of faculty and students; (2) identify directions for future regional conferences; (3) promote faculty and students interactions; and (4) explore submitting joint proposals to funding agencies.

Faculty, staff and students from eight KEEN Schools (Baylor University, Calvin College, Illinois Institute of Technology, Lawrence Technological University, Mercer University, Milwaukee School of Engineering, Saint Louis University, and University of Detroit Mercy) participated and presented their projects and research work on invention, innovation, and entrepreneurship and discussed possible collaboration among KEEN schools and future direction for the KEEN regional conferences. More than a hundred faculty, students, administrators, and industry personnel participated in the regional conference.

For future regional conferences, the faculty participants recommended the following:

- face-to-face meetings to begin collaborations allowing student and faculty to interact;
- panel of faculty advisors in different areas (patent applications, marketing, design for manufacture/assembly etc.) allowing students to ask questions in their specific areas of need relating to their project;
- more opportunity for networking or regional faculty development opportunities;
- seed grants for KEEN colleges to submit joint proposals to funding agencies;

- opportunity to bring students to regional conferences;
- effective faculty development workshops; and
- students work together on projects across the network.

The student group came up with the following recommendations:

- data base of skills and equipment available on the KEEN website;
- entrepreneurship camp that is run by an entrepreneur;
- student network on the KEEN website;
- business incubator to help students launch their business ideas;
- members of the KEEN network review student projects 1-2 months before (when first prototype is created);
- professors at different schools teach classes over the internet to get a different perspective on entrepreneurship;
- record guest speakers and make them available to other KEEN colleges or do it live over the internet;
- summer exchange program between schools;
- program that allows students to shadow entrepreneurs; and
- podcast every two weeks in which an entrepreneur sends in a problem and students can present their solutions.

4. Mercer Entrepreneurship Student Club

Mercer Entrepreneurship Student Club (MESC) started in 2007, as part of MEEEP to promote students activities on innovation and entrepreneurship across Mercer campus. More than 60 engineering students through MESC are actively engaged in: recruiting students to the entrepreneurship program; participating in the entrepreneurship certificate program; taking entrepreneurship related courses; participating in entrepreneurial senior design projects, listening to successful entrepreneurs through invited speakers and seminar; developing business plans and competing in the design and business plan competitions; promoting activities during national entrepreneurship week; raising funds to participate and present technical papers on their senior design and business plans through “Cookout” lunches and dinners and selling T-shirts that were designed and made by entrepreneurship club students; presenting technical papers in the national and international conferences; and actively participating in the activities of the recently established “Center for Innovation and Entrepreneurship” that includes participating in the KEEN Regional Conference on Innovation and Entrepreneurship, held at Mercer University School of Engineering during September 16-17, 2010 and interacting with the faculty and students from other KEEN schools.

5. Entrepreneurial Design Projects

Selected entrepreneurial senior design projects involving business plans and product design competition during the academic years 2007-2010 are briefly discussed below:

The Drop Foot Device: This device was designed to treat patients with drop foot due to the damage of common peroneal nerves. A motor, sensors, and microcontroller were used with ankle foot orthoses to construct the device. The device was selected to patent by Mercer University Research Office (It was chosen for patenting in 07-2008, U.S. Patent No. 60/928,562).

Elbow Brace: The purpose of the device is to provide stability of the elbow joint in three planes of motions for post-op elbow surgeries. A 3D elbow brace simulation model was developed using Solid Work and analyzed to determine the optimal stresses and dimension of the design. The elbow brace was then designed, built, and tested by the student team.

Microcontroller Knee Prosthesis: The knee prosthetic device composed of a tiny DC motor, microcontroller, shape memory alloys, and pressure sensors. Inventors Socket scan and Matt scan were used to analyze the stresses, and gait analysis.

Alarm Insole Sensor for Diabetes: The sensor insole was designed using pressure sensitive sensors and alarm alerting system to measure the highly abnormal peak pressure of the bottom of the diabetic foot to prevent developing unexpected pressure sores/ulcers of diabetic neuropathy foot. The device was built and tested by a student team.

The Solar Golf Cart: Regular golf car is redesigned using the solar cells as necessary energy to operate the cart. Two 24-volt rechargeable batteries were used to restore the solar energy for maintaining the required energy to operate the cart.

Low Cost Universal Socket Prostheses: The universal socket was designed and built in 6 pre-made sizes using polypropylene, soft cotton liner, aluminum pipes, and SACH foot to benefit the amputees in the third world countries. The low cost universal socket prostheses were designed as part of "Mercer on Mission to Vietnam" program and the Mercer faculty and student team during the summer of 2009 and 2010 fitted the prostheses for the needed below–knee and above-knee amputees in Vietnam. This project received national recognition and financial commitment from Clinton Global Initiative University. A provisional patent has been obtained for the low cost universal socket and a Mercer faculty team is planning to start a start up venture in Vietnam to provide low cost prostheses to needy patients in Vietnam and other Asian countries.

Design and Fabrication of Automatic Power Switch for Renewable Energy Sources: The goal is to design a switch that must be able to handle up to 240 volts and 200 amps to transfer a modern household from a renewable source of energy to the grid and back again whenever the renewable source is able. The switch is to change between sources (in less than 10 milliseconds) with minimal disruption to normal electrical operations: not to have computers shut off; and electronics such as digital clocks not to lose power long enough to reset.

Infrared Multi-Input System: Two different input devices were constructed that emit infrared light using infrared LEDs that can be detected by the Wii™ remote to interact with the user's PC. Pushing the button on the LED pen will activate the LED, which is detected as a "left mouse click" when using the software application. The LED gloves use two infrared LEDs on each hand one mounted on the tip of the index finger, and another mounted on the tip of the thumb to do the pinching motion that will cause the system to detect a "left mouse click".

Design of a Laser Kit for High School Students: A laser kit was designed and developed that would grant students of a high-school level the opportunity to learn basic physics principles using the laser and instruction manual to gauge their understanding by having them complete a demonstration. Other specifications include portability, output power (must be between 2-5mW), and the ability to run off of battery DC power as well as have the option to plug into a wall outlet to convert AC to DC power with a minimum cost.

Retrofitting of Tabletop CNC Lathe[1]: This project describes the infusion of new technology and the resulting extended useful life of an 18 year old computer numerical controlled (CNC) tabletop lathe. Key to the success of the project was the ability to have a low cost, high performance real-time controller that was compatible with the existing electrical components of the lathe. The Enhanced Machine Controller (EMC) Project software installed on a personal computer running a Linux Operating System was the basis of the new controller design. Artifacts were created using G-codes from existing models. The retrofitted lathe is currently being used in the Intelligent Manufacturing Systems Lab at Mercer University for teaching computer aided manufacturing and providing hands-on experience to students taking manufacturing courses (Figure 1).

(a) **(b)**

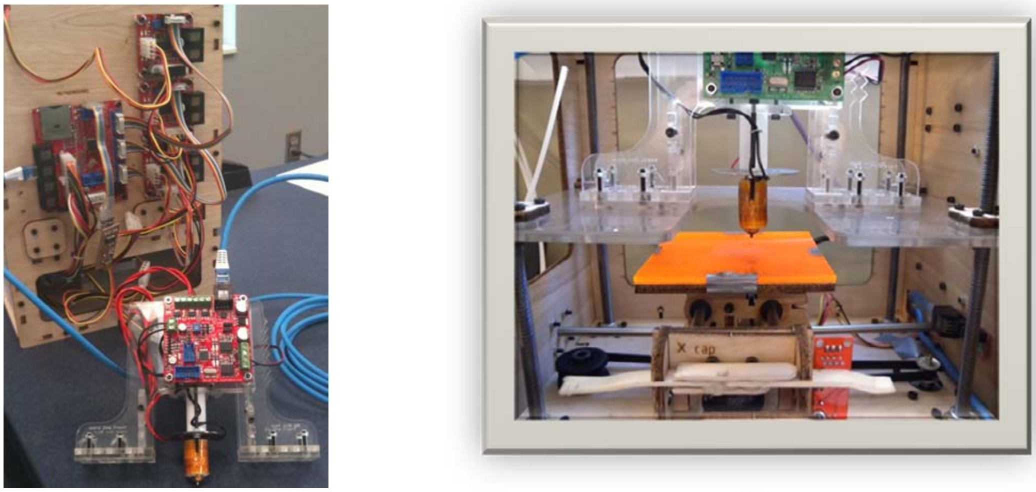
Figure 1. Tabletop CNC lathe: (a) Retrofitted and functional; (b) Artifact made[1]

Affordable Prototyping with the MakerBot Cupcake[7]: The MakerBot Cupcake CNC machine that uses additive manufacturing technology to create objects made of Acrylonitrile Butadiene Styrene (ABS) was assembled and made operational. It converts a 3D model to a usable physical object. Alterations such as reducing idler wheel thickness, using a higher grade material for the insulation between the heater barrel and the rest of the extruder, and fabricating a removable heat source were made to the machine to ease maintenance and improve reliability.

The MakerBot consists of a wooden frame, a build platform with X and Y pulleys for movement, and a Z platform on which the extruder sits. The extruder, and the X, Y, and Z stepper motors all have a circuit board which is connected to the Cupcake's motherboard (Figure 2). Cupcake uses additive technology to form 3-D parts, which is ideal for prototyping and manufacturing a small number of parts. Additive technology allows the capability to print interior structures. The following steps were taken to achieve successful operation of MakerBot:

- Downloading software
- Testing motors independently for vibration and backlash

- Testing extruder for idler wheel and heater barrel
- Printing: misprints or successful prints



(a) (b)

Figure 2. MakerBot: (a) circuit board details; and (b) assembly.

Using the MakerBot, a whistle was successfully printed as shown in Figure 3. The interior ball did not come free from the bottom wall, and it is possible that this is a complication of the nozzle being too close to the Z platform at the start of the build, or an error in the G-codes. The whistle is a good example to print because of its interior features. The whistle is hollow with an interior ball, which cannot be achieved using a traditional milling machine.

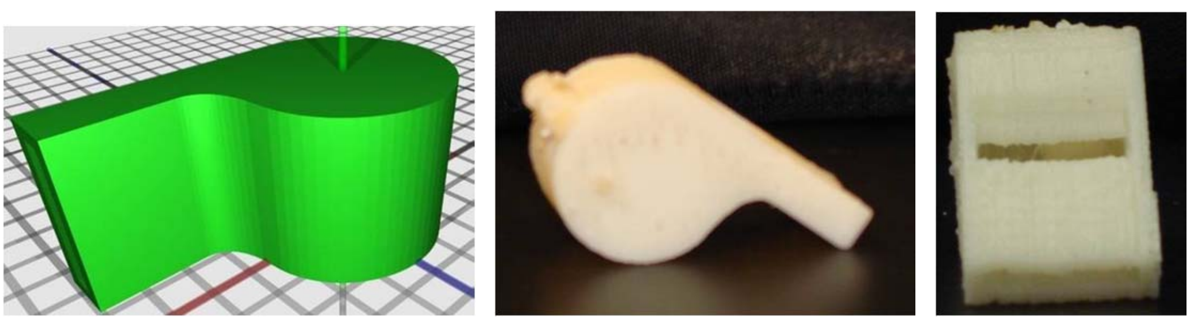
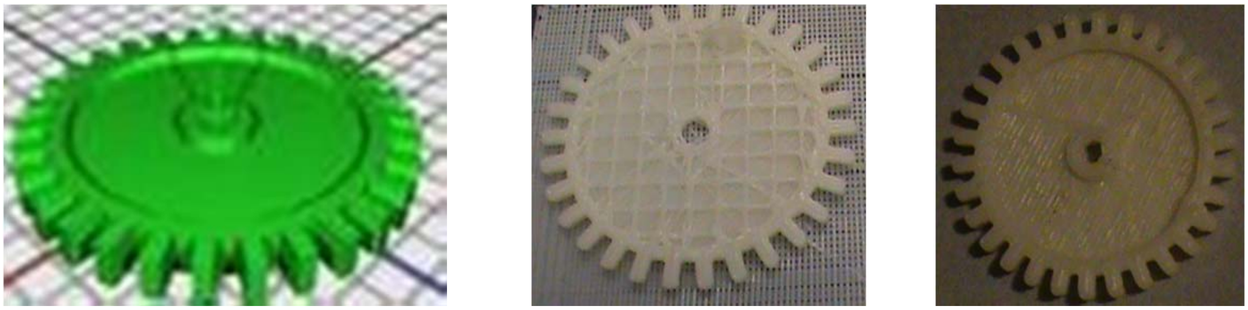


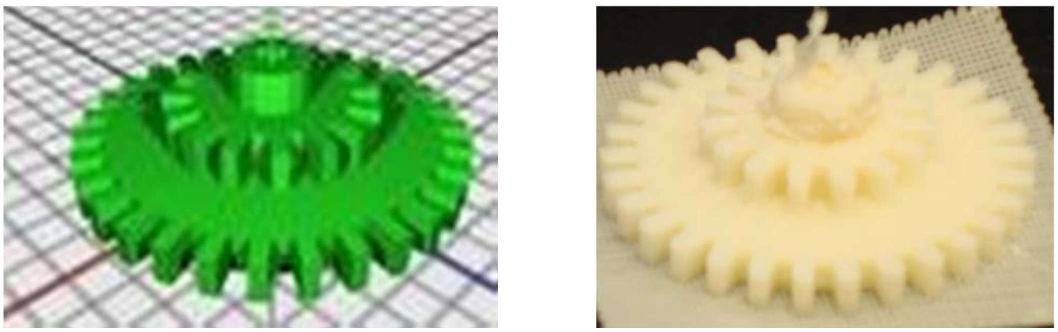
Figure 3. Printed part - different views of the whistle.

Single and double gears were printed that have a hollow honeycomb interior, which reduces use of unnecessary ABS filament. This can be seen in the interior of the gear. Both the single and double gears were printed and different views of the gears are shown in Figure 4.

The 3D printer is currently being used in the Center for Innovation and Entrepreneurship for teaching the concept of additive manufacturing and rapid prototyping to undergraduate students in engineering. The printer has already been used by a number of student teams working on their senior design/research projects to print their parts and prototypes.



(a)



(b)

Figure 4. Different views of (a) single gear and (b) double gear.

Student teams of all the projects discussed in this section participated in the annual business plan/entrepreneurial senior design project competitions held at MUSE. Some of the projects were presented in the BME, ASEE, KEEN, NCIIA, IEMS, and ICMES conferences and published in the conference proceedings

6. Program Assessment

The effectiveness of Mercer entrepreneurship program has been critically assessed and evaluated during 2007-2009 using:

- the comprehensive evaluation plan already in place recommended by KEEN advisory team to assess entrepreneurial mindset;
- assessment plan (rubrics) developed for all the entrepreneurship courses offered;
- the factors such as number of entrepreneurship courses taught, number of student enrollment, number of entrepreneurial design projects in the program, number of faculty and alumni participation in the program, support from administration, number of internal and external grants obtained, number of student entrepreneurship club activities, and number of students participation in national and regional competitions as well as conferences;
- exit interview from seniors graduating from Entrepreneurship General Education Program, Mercer on Mission to Vietnam Program, and other programs developed through the Center for Innovation and Entrepreneurship;
- faculty/alumni teams to advise and evaluate the entrepreneurial senior design projects; and
- Georgia based entrepreneurs to serve as advisors/mentors to student project design teams as well as judges for entrepreneurial senior design and business plan competitions.

In fall semester of 2010 KEEN–TTI assessment project was used in assessing freshmen through seniors by administering the KEEN–TTI performance DNA. More than a hundred students took the survey and the results are being analyzed by the assessment team.

7. Sustainability

Other faculty members across the Mercer Campus are being encouraged to participate in the entrepreneurship program. Currently the entire faculty from school of engineering, some faculty from business, medical, and law schools and more than 100 active engineering and non-engineering students are participating, promoting and enhancing entrepreneurship activities across the Mercer campus.

Mercer's entrepreneurship faculty team is actively seeking funds from government funding agencies, private foundations, local industries and Mercer alumni. So far the team has received funding from NCIIA in addition to Kern family foundation grant. Kern Family Foundation approved additional funding for two more years (2009-2011) in order to expand the entrepreneurship program across the Mercer campus. In addition, through AIM funds, the development of center for innovation and entrepreneurship is taking place.

Mercer's entrepreneurship program is actively developing network of outside financial support: from Mercer alumni, local industries, successful entrepreneurs, state and local governments, Angel Investors Group etc. Some of Mercer's alumni have already come forward to actively participate and contribute financially to senior design projects. Participating faculty members are planning to seek additional funding for the program by submitting proposals to other extra mural funding agencies.

8. Future Work

The CIE and MEEEP will concentrate on educational as well as scholarly activities. The educational opportunities will be focused on developing and offering a minor in entrepreneurship across the Mercer campus covering all aspects of invention, innovation, creativity, and entrepreneurship. The courses will focus on project/case-based teaching and learning. The scholarly activities will initially focus on the development of low-cost medical devices, and cost-effective alternate energy technologies. There will be opportunities for innovative interdisciplinary initiatives by the faculty and students from all participating schools and colleges. Findings from the research conducted at the center will be presented at national and international conferences and published in journals and conference proceedings.

The CIE will (1) provide stipend for engaging undergraduate and graduate students in interdisciplinary research; (2) train the faculty and students in the development of an entrepreneurial mindset through workshops and seminars; (3) provide funds for participation in KEEN and NCIIA conferences; and (4) purchase machines and equipment for research in manufacturing, biomedical, and energy systems.

The products that will be produced from the CIE activities include but are not limited to: development of low-cost machines/equipment, medical devices, equipment/devices for alternate energy sources, presentation of research results in regional/national/international conferences, publications in journals and conference proceedings, and students taking entrepreneurship minor/elective courses; curricula, instructional materials, tools and techniques, patents, protocols, resource manuals, project reports, training sessions/workshops, and conferences; increases in undergraduate/graduate student enrollment and development of national and international collaborative studies/projects through networking.

9. Results and Conclusions

The entrepreneurship certificate program established in 2007 is expanding and achieved a number of mile stones: Engineering, Business, Medical, and Law faculty members are actively engaged in promoting entrepreneurship program across the Mercer campus through the Center for Innovation and Entrepreneurship; both graduate and undergraduate students are attracted to the entrepreneurship related courses; a number of entrepreneurial senior design projects were funded and the student teams participated in the "Business Plan Competitions" as well as presented their design projects in regional, national, and international conferences. Some of the design projects received regional and national recognitions/awards during the period 2007-2010. The entrepreneurship program and assessment results are summarized in Table 2.

Table 2: Entrepreneurship program results

Program Outcome	Year 2007-08	Year 2008-09	Year 2009-10
Students impacted (courses/modules)	30%	60%	100%
Entrepreneurial senior design projects funded	2	5	8
Students participated in business plan competition	-	22	30
Recognition and awards to student projects	1	2	3
Students participated in conferences	5	10	20
Student participated in entrepreneurship club activities	30	40	60
Faculty participation in conferences	7	15	20
Proposals submitted for funding	3	5	7
Faculty participation in workshop and training	4	5	28
Regional conference participated and/or organized	1	2	3
International conference organized (ICMES)	-	1	1
Papers presented in conferences	6	10	16
Invited speakers	2	5	7
Fundraising events	2	3	5
Graduates working as intrapreneurs	5	7	9
Commercial products developed	1	2	2
Patents applied	1	1	2

The entrepreneurial design projects discussed in this paper are shared among KEEN schools. The learning objectives defined for these projects were successfully accomplished by the student teams and written instructions are available for most of the projects.

The challenges encountered in the early stages of the entrepreneurship program at MUSE include but not limited to the following:

- involving the upper administration for promoting the entrepreneurship program;
- recruiting students and faculty for the program;
- promoting entrepreneurial mindset among students interested in entrepreneurial program;
- seeking additional funding for the long term program sustainability;
- developing a network of outside support (mentors, judges, and advisors for the student projects); and
- engaging engineering faculty to teach courses related to entrepreneurship program.

There is still reluctance from engineering faculty to promote and support the entrepreneurship program at MUSE. There is interdepartmental/administrative reluctance to promote and expand the entrepreneurship program within/outside the School of Engineering.

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Building Engineers and Mentors: A Model for Student-Led Engineering Outreach

AJ Almaguer

Abstract

Two years ago it became apparent that there was high demand among engineering and science students to do outreach and community service. However, the options at the time were limited and not well-developed. It was also difficult to train dynamic mentors capable of teaching science and engineering concepts to a younger audience. In an effort to address this problem, we created Building Engineers and Mentors (BEAM) to serve as an infrastructure to train mentors and deploy them at local k-12 schools and community partners. It is a student-run organization and a course offered at UC Berkeley. BEAM has made great efforts to constantly evolve, assess, and redesign itself into a flexible program to achieve our mission: to impact the future of students in our community through hands-on learning. It is our belief that BEAM serves as a model for effective student-led outreach and education partnerships between universities and their surrounding educational institutions. Our ten-week course consists of a day-long mentor training followed by a guest lecture series, weekly volunteer site visits, and a final project. The course adheres to engineering and education principles including: ABET Criteria, engineering design loop, and bloom's taxonomy. Leadership development also plays a center role in our program and we have developed a complete leadership structure to provide longevity to BEAM. The performance of the organization is assessed by three criteria: (1) development of leadership skills in our mentors through the final project; (2) development of our mentees through a "Draw an Engineer Test"; (3) changes in our mentees' attitudes towards engineering through self-reported competencies. Mentors particularly cited BEAM increased their ability to lead, think creatively, and recognize the broader impact of engineering. Our mentees showed notable changes in their conceptions about engineering and science through the Draw an Engineer Test. In the near future, BEAM intends to collect more quantitative data from both the mentors and mentees through surveys and worksheets. Additionally, we hope to obtain data from outside sources such as the parents of mentees and schools.

Introduction

Two years ago, it became apparent to us that there was a strong desire to participate in engineering-related outreach on the part of the students. Many student organizations such as the Hispanic Engineers and Scientists, Pi Tau Sigma, Society of Women Engineers and other similar groups each had their own unique k-12 outreach programs while other organizations like Engineering 4 Kids Day were piloting their own unique contributions. In interviewing undergraduate students we found consistency in the obstacles that they faced: (1) students were either unaware of the opportunities for outreach or did not find a right match with the organizations that provided such opportunities; (2) outreach was considered insignificant compared to their coursework. There was a general attitude that outreach was not "technical enough" for engineers and the benefits of community service were not apparent enough to students; (3) it was hard to train mentors that were capable of teaching science and engineering concepts to a younger audience.

We believe that community service builds strong, empathetic leaders. With this in mind, we tackled this design problem like engineers would and specified the user needs of students like ourselves, our k-12 mentees, and the university—our primary stakeholders. After many brainstorming sessions, we concluded that we have three main user requirements: (1) professional development, (2) the need for practical, technical experience—a chance to put our engineering education into practice, and (3) formal mentor training.

We used results from a recent a study[1] performed by the Lawrence Hall of Science (LHS) and our own experiences to define user requirements for our k-12 mentees including the need for more exposure to science and engineering as well as the need for fun, engaging activities. Additionally, we defined some user requirements for our university, which include the need to recruit potential students and conduct outreach within the financial constraints of a public university. The slogan for the College of Engineering is "Educating Leaders, Creating Knowledge, Serving Society" and hence we aimed to meet the need to develop alumni with strong leadership skills.

In an effort to address these problems and meet the user requirements, we joined efforts with our fellow student leaders and created Building Engineers and Mentors (**BEAM**), which is now a student organization, and a course at the university. BEAM is a group of engineering and science students that develop and teach hands-on lesson plans at K-12 schools in the local community. We also train college students to be effective mentors, role models, and leaders in their community. Being students ourselves, we understand that the best way to learn is by teaching and by doing. Participants can earn course credit while improving their mentoring and leadership skills.

BEAM operates a student-run class to train our mentors and to develop leadership skills in our members. BEAM serves as a model for effective student-led outreach and education partnerships between universities and their surrounding educational institutions. Our program has been designed to contribute to greater diversity and access to engineering while serving the needs of our primary stakeholders. For two and a half years, we have planned, implemented, assessed, and redesigned a flexible organization to achieve our vision: to impact the future of students in our community through hands-on learning. This paper will explain the details of our program, show preliminary quantitative and qualitative evaluations, and discuss our plans for the future.

Organization and Methods Employed

BEAM was founded with the support of the College of Engineering, several faculty members, and the university's Public Service Center. In the fall semester of 2010, BEAM evolved into a student-taught course and team of 60 mentors who teach at eleven k-12 schools in the surrounding community. The following subsections describe details of this work.

What is unique about BEAM?

BEAM is structured to encourage mentors to take initiative and develop their leadership skills early on in their involvement. For example, at the end of the 10-week semester, mentors take ownership of the curriculum design process by creating unique lesson plans. The students have the opportunity to not only execute a set curriculum at the mentoring sites, but also gain experience in the curriculum design process. These lesson plans are then implemented and carried out by the mentors as the final lesson plan for the school semester. By doing so, the student mentors involved with BEAM take on the role of teachers and leaders instead of just volunteers working with k-12 students.

Another unique aspect of the program is the coupling of engineering outreach with a mentoring training course, which is described below. Students concurrently work in the field and also have an engineering and conceptual basis in a course. Our program is method-driven in that students are given training, relevant scientific knowledge, and reflective discussion opportunities to improve the quality of mentoring.

The program is also unique in that it offers different levels of involvement for the mentors. On one hand, students can enroll in the BEAM mentor training course and teach at an after-school program. However, BEAM has partnered with the Lawrence Hall of Science and its Ingenuity Lab to offer students a chance to guest mentor once to see if BEAM is right for them. This flexible system allows involvement from college students who are passionate about teaching, whether they can devote a large amount of time or only for a few hours a month.

How is BEAM connected to other outreach programs?

BEAM adheres to engineering education principles. We designed BEAM with the following pedagogical practices in mind: (1) adherence to the ABET Criteria used for graduating engineers; (2) use of an elementary 5-Step Engineering Design Process for teaching engineering principles; (3) use of Bloom’s Taxonomy[4] for training mentors in levels of learning and development of appropriate lesson plans; and the use of learning styles as defined by Felder[3] to create inclusive educational plans. With these principles in mind, we developed the learning objectives for BEAM mentors and mentees. These learning objectives are outlined below.

Mentor Learning Objectives:

1. Explain the 8 learning style domains, the 6 levels of learning (Bloom's Taxonomy) and the ABET learning outcome objectives.
2. Apply the elementary 5 step design process.
3. Design a k-12 level teaching plan for an applied science or engineering topic that address the eight learning style domains (active-reflective, verbal-visual, intuitive-sensing, global-sequential).
4. Develop lesson plans that implement the six levels of learning as defined by Bloom's taxonomy (L1-L6).
5. Develop assessment tools to evaluate the effectiveness of teaching plans and mentoring.
6. Function effectively on a team, with effectiveness being determined by instructor observation, peer ratings, and self-assessment.
7. Create learning environments that foster all elements of the ABET learning outcome objectives.

Mentee Learning Objectives

1. Identify an important contemporary technical challenge of a regional, national, or global nature that involves or utilizes engineering.
2. Describe the basic engineering design process and its use in solving technical challenges.
3. Discuss ways engineers might make important contributions to solving problems.
4. Remember or summarize key facts and concepts taught in each lesson plan.
5. Explain technical concepts in their own words.

BEAM uses the 5-step design process (Figure 13) developed by Boston Museum of Science (Engineering is Elementary)[5] in our education plans owing to its simplistic terminology and ease of use in the k-12 domain.

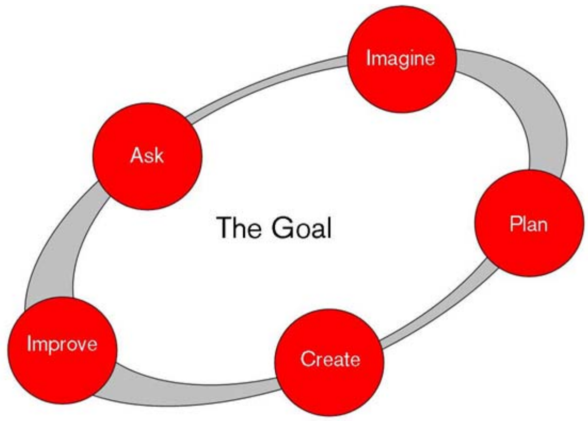

Figure 13: The Engineering is Elementary® 5-Step Engineering Design Process

Protocol for conducting outreach

BEAM has a standard protocol for conducting engineering outreach. For 10 weeks of the semester, our mentors volunteer at several after school programs for about 1.5 hours per week. Volunteer sessions occur Tuesdays-Fridays. Mentors receive training on the week's lesson on Monday nights. More detail of this mentor training can be found in the following section. In the Fall of 2010 we sent mentors to 11 after school programs at 8 elementary schools and 2 high schools. Some of our mentors also worked an hour per week at the LHS Ingenuity Lab. We call each program a "site" and each site is managed by a "site leader," an experienced BEAM mentor.

In the Fall of 2010 there were a total of about 150 mentees participating in our after school programs. We maintain a high mentor-to-mentee ratio (usually 1:3 or 1:4) at our sites. Our mentors are assigned to a few students with whom they will work with personally for the entire semester.

We design lessons and activities that tap into kids' natural inclination to tinker and explore, making sure that every lesson plan has a hands-on component, which allows the mentees to design and build something and/or engage in an active exploration. Most of our activities are completed in teams, emphasizing communication and joint problem-solving. Lesson plans fall into three categories: *module-based*, *project-based*, or *challenge-based*. Table 10 gives a description of each category. The curriculum team ensures that the syllabus covers concepts from all the major engineering disciplines. The list of lesson plans for Fall 2010 is given in Table 11.

When developing lesson plans, we take full advantage of the fairly comprehensive collections of engineering lesson plans that already exist including but not limited to: teachengineering.org, howtosmile.org, make magazine, Instructables.com, etc. As we gain experience in designing lesson plans we hope to eventually make our own contributions to these communities.

Module-based	These lesson plans teach an overarching engineering concept or principle through the use of "modules." Each module is a different activity that helps students understand the concept. The goal of these lessons is to break down the overall concept into more manageable sections. Mentors have the choice of dividing the mentees into groups that rotate through each module.
Challenge-based	Challenges focus on the engineering design process. Mentees are given a challenge and are asked to go through the design process to come up with a solution, test it, and redesign it.
Project-based	These projects are designed to succeed. They provide working models and examples that prominently illustrate certain engineering concepts. Mentors guide the mentees in building the project.

Table 10: Description of lesson types.

Week	**High School Lesson Plan *(lesson plan type)***	**Elementary School *(lesson plan type)***
1	Build a kinetic sculpture (challenge)	Build a lava lamp (project)
2	Build LED Lightbox (project)	Build kinetic sculpture (challenge)
3	Build LED Lightbox (project)	Build Stomp Rocket (challenge)
4	Build a skyscraper (challenge)	Build a skyscraper (challenge)
5	Build a skyscraper, week 2 (challenge)	Build a skyscraper, week 2 (challenge)
6	Build a stomp rocket (challenge)	Learn about acid rain (module)
7	Build a scribbling machine (challenge)	Build a scribbling machine (challenge)
8	Learn about polymers (module)	Learn about polymers (module)
9	Build a heat shield (challenge)	Build a heat shield (challenge)
10	Mentor-developed lesson plan	Mentor-developed lesson plan

Table 11: Syllabus for Fall 2010

Mentor Training

Mentor training is an important aspect of the BEAM program and there has been considerable effort in developing appropriate protocols for this educational process. In order to accomplish the goal of the program to ensure the quality of mentorship, we train our mentors through a semester-long course. The course comprises of a mentor training workshop, a 10-week weekly class with a guest lecture series (which usually falls on Monday nights), and a final project. Mentors can receive 2-3 units for taking the course. Course attendance is mandatory for all receiving units and is strongly encouraged for mentors who decide to not take the course for units.

The mentor training workshop is a day-long event held at the Lawrence Hall of Science and is held the weekend before the first week of mentoring. Students participating in the BEAM program and mentoring course are required to attend this training. This event features a keynote speaker and several rotating workshops. Each workshop is given by an educational professional and features a different mentoring technique.

The guest lecture series invites professors, graduate students, and educational professionals to give a half hour lecture on topics related to the state of science education and their own mentoring experiences. These lectures occur during the Monday night classes and are meant to inspire and stimulate productive conversations among the mentors.

Since BEAM is a science and engineering educational outreach group, the remaining hour of the mentoring course is allocated for teaching students the scientific background and to familiarize students with the activity of the week. Half an hour is dedicated to the theoretical concepts for each lesson. This is important because the participating mentors are from various engineering and science (or even non-science) backgrounds, and the lesson plans taught each week cover, to some depth, knowledge from a particular field. The last half hour of the class is used to complete the science or design activity for that week of mentoring. Despite its conceptually simple nature, this segment of the mentoring course is of great importance. All the mentors in BEAM are required to have successfully completed the activities that the mentees have to complete. This way, the students can provide better assistance and guidance both in the conceptual basis of the activity and the actual construction of the project.

The mentors are also required to complete a final project to pass the course. In the final project, mentors are asked to design, implement, and assess a novel lesson plan. This exercise gives mentors a taste of curriculum planning and allows them to gain a wider range of skills in mentorship. Students are given comprehensive guidelines for the project including sections on: teaching plan, scientific background, method of topic introduction, list of demonstrations, main activity, closing discussion, and a summarizing worksheet. The guidelines also include a bill of materials, learning styles assessment, and references. A five minute pitch of the lesson plan and a formal presentation (given after teaching) are the deliverables. This project gives the mentors a larger role in the content and leadership of outreach and also allows BEAM to be sustainable and develop an ever-increasing pool of lesson plans.

Leadership Structure

BEAM is structured like a small business. We pulled many ideas from our past internship and research experiences. BEAM members are encouraged to be leaders from the very beginning. The system is designed to allow incoming mentors to slowly attain more leadership and responsibilities. Mentors and mentees are at the base of the leadership structure. They are lead by the BEAM staff, which is sub-sectioned according to roles (i.e. site facilitators, curriculum team, etc). The leadership structure is mapped out in Figure 2.

By the third week of mentoring, site facilitators encourage mentors to take the lead and facilitate the lesson themselves. This gives the mentors practice before designing and teaching their own lesson plan as part of their final project. Mentors enrolled in the course are given the responsibility to assess the learning objectives of their own mentees in their final project. Returning mentors are encouraged to become staff, adding to their responsibilities and giving them more practical leadership experience.

Mentors also have the option of becoming staff in one of the other BEAM teams: Curriculum, Sites, Finance, Marketing, Logistics, Internal Affairs and Web Development. Each team is lead by a vice president, who works with two co-presidents in the executive team.

This leadership structure has been developed to provide longevity to BEAM. By assigning mentors to defined teams and heading each team with an experienced leader, the structure ensures that each job is passed on to capable successors. Additionally, the presidents have overlapping terms to make sure that there is always an experienced president on staff. This new system has given us the flexibility to grow as an organization by increasing the size of the teams and by creating new teams as new needs arise.

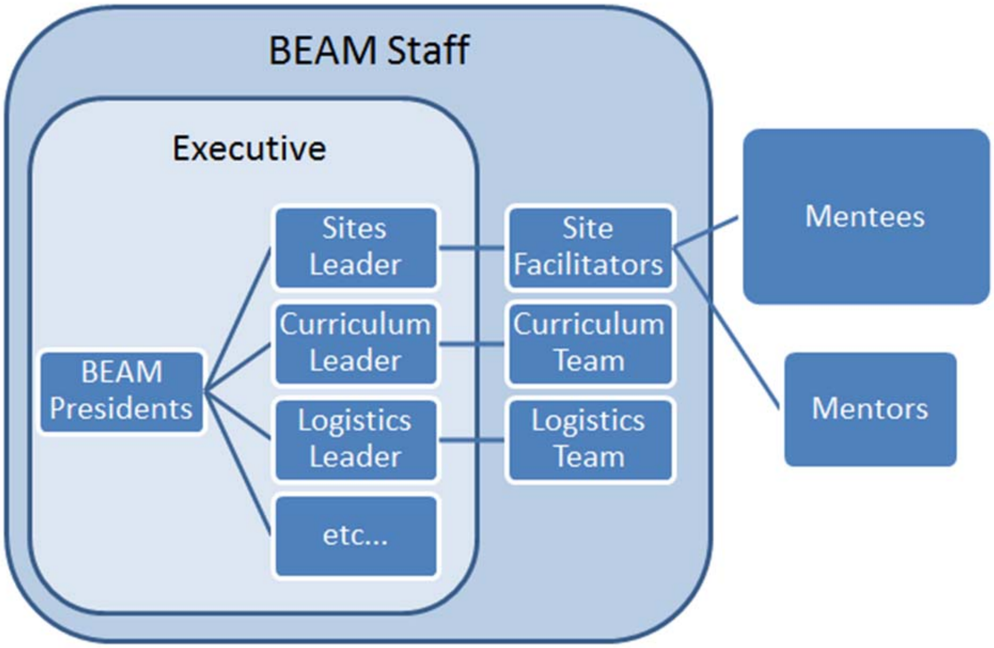

Figure 14: BEAM staff organization

Assessment

The performance of the organization is assessed by three criteria: (1) development of leadership skills in our mentors (2) development of our mentees and (3) changes in our mentees' attitudes towards engineering. Development of assessment methods was guided by our learning objectives.

One of the goals of BEAM is to increase participation in engineering and engineering programs by minorities and girls. To ensure this, surveys were given out to determine the demographics of our mentors and mentees.

We developed two tools to assess the learning objectives of our mentors. First, in order to assess the self-development of the mentors, two identical surveys were given at the beginning and end of the semester. Mentors were asked to rate 11 personal skills such as leadership and creativity on a scale from 1 (low) to 5 (high). In the final survey, mentors were also asked to retrospectively rate their competency at the beginning of the semester.

In addition, mentors were required to blog about each weekly mentoring session. The purpose of the blog is to aid reflection and help mentors verbalize their mentoring experiences. At the start of each mentoring class, mentors are encouraged to discuss strategies that worked or failed at their sites the previous week. Feedback from the weekly blogs is shared and analyzed together.

One form of assessment used to evaluate the primary school mentees is the Draw an Engineer Test, an adapted form of the Draw a Scientist Test[2] (DAST). The test was administered before and after the 10 week program to gauge the ideas and preconceptions about science and engineering held by our mentees. By comparing the results and identifying key themes and trends in the students' drawings, we were able to qualitatively judge the impact our outreach program had on attitudes about technical careers.

Mentors also developed their own forms of assessment and reported the results as part of their final project.

Results

The achievement of mentor and mentee learning objectives is used to quantify the success of the BEAM program. The various assessment activities (mentor survey, draw a scientist test, final projects, etc) implemented provided a vehicle for qualitative and quantitative outcomes. This section will outline and describe the outcomes for the program via the learning objectives and assessment activities.

Demographics

BEAM is committed to increasing the diversity of the student population it serves. BEAM strives to recruit a diverse team of mentors and reach a diverse group of children. A breakdown mentor and mentee demographics are found in Figure 3

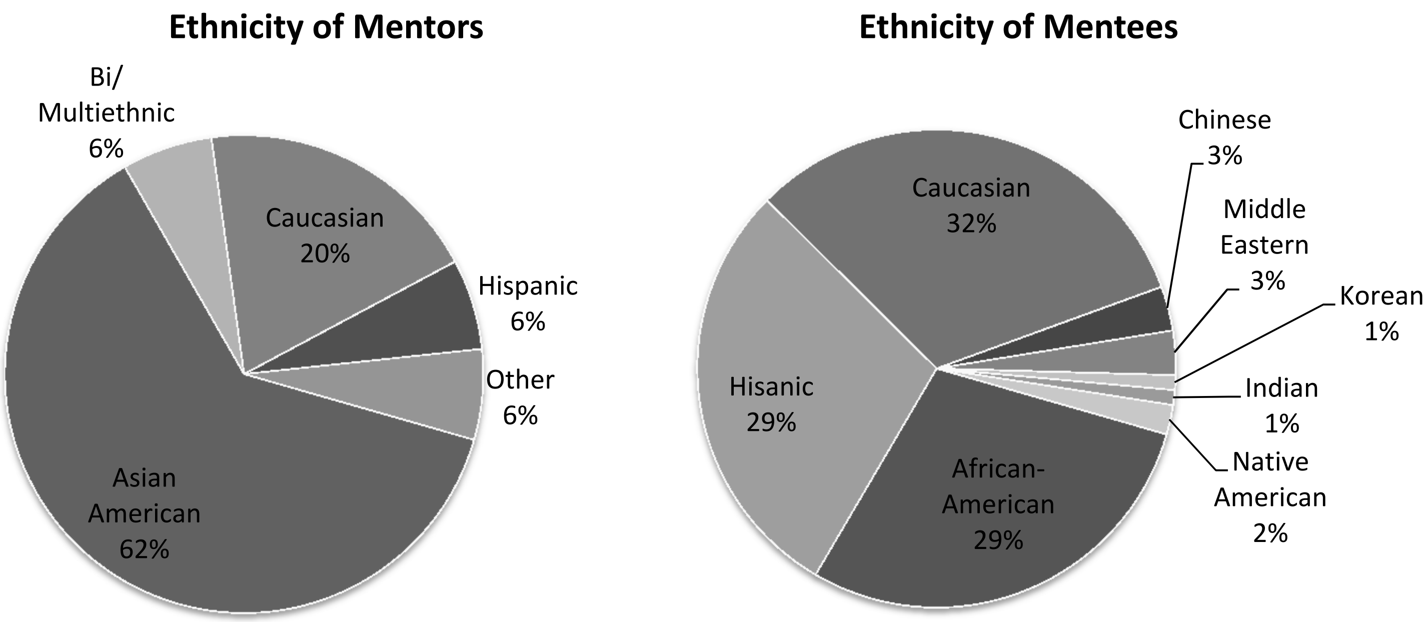

Figure 15: Ethnicity data for mentors and mentees.

Mentor Self-Assessment Surveys

Mentors were asked to rate their competencies through two self-assessment surveys. On average, the mentors reported improvements in all the learning objectives over the course of the semester (Figure 16). Table 12 shows the questions asked. Twenty-six mentors responded to the survey. Comparing retrospective responses to "after" responses, the largest improvements were in “exhibit creativity and practical ingenuity," "dynamic/agile/resilient/flexible," and "ability to recognize the global economic, environmental, and societal impact of engineering design and analysis." In general, these trends are repeated comparing the "before" responses to the "after" responses.

Responses to question 2 indicate that mentors were overconfident about their creative skills before participation in BEAM. This also indicates that mentors felt that they improved more than they had anticipated. Responses to question 7 indicate that mentors felt they had underestimated their leadership skills at the beginning of the semester. The "after" responses show that mentors gained more confidence as leaders.

Responses to questions 1 and 8 seem to indicate that mentors felt BEAM had little impact on their analytical skills or standards of professional conduct. The response to question 8 could have stemmed from the fact that it was poorly worded and incorporated two different concepts (ethics and professionalism) into one question. A way to improve this issue would be to ask two separate questions.

1	Possess strong analytical skills.
2	Exhibit creativity and practical ingenuity.
3	Ability to develop designs that meet needs, constraints and objectives.
4	Ability to identify, formulate, and solve engineering problems.
5	Good communication skills with multiple stakeholders.
6	Good team skills with people from diverse backgrounds and disciplines.
7	Leadership and management skills.
8	High ethical standards and a strong sense of professionalism.
9	Dynamic/agile/resilient/flexible.
10	Ability to learn and use the techniques and tools used in engineering practice.
11	Ability to recognize the global, economic, environmental, and societal impact of engineering design and analysis.

Table 12: Mentor-Self Assessment Skill Areas

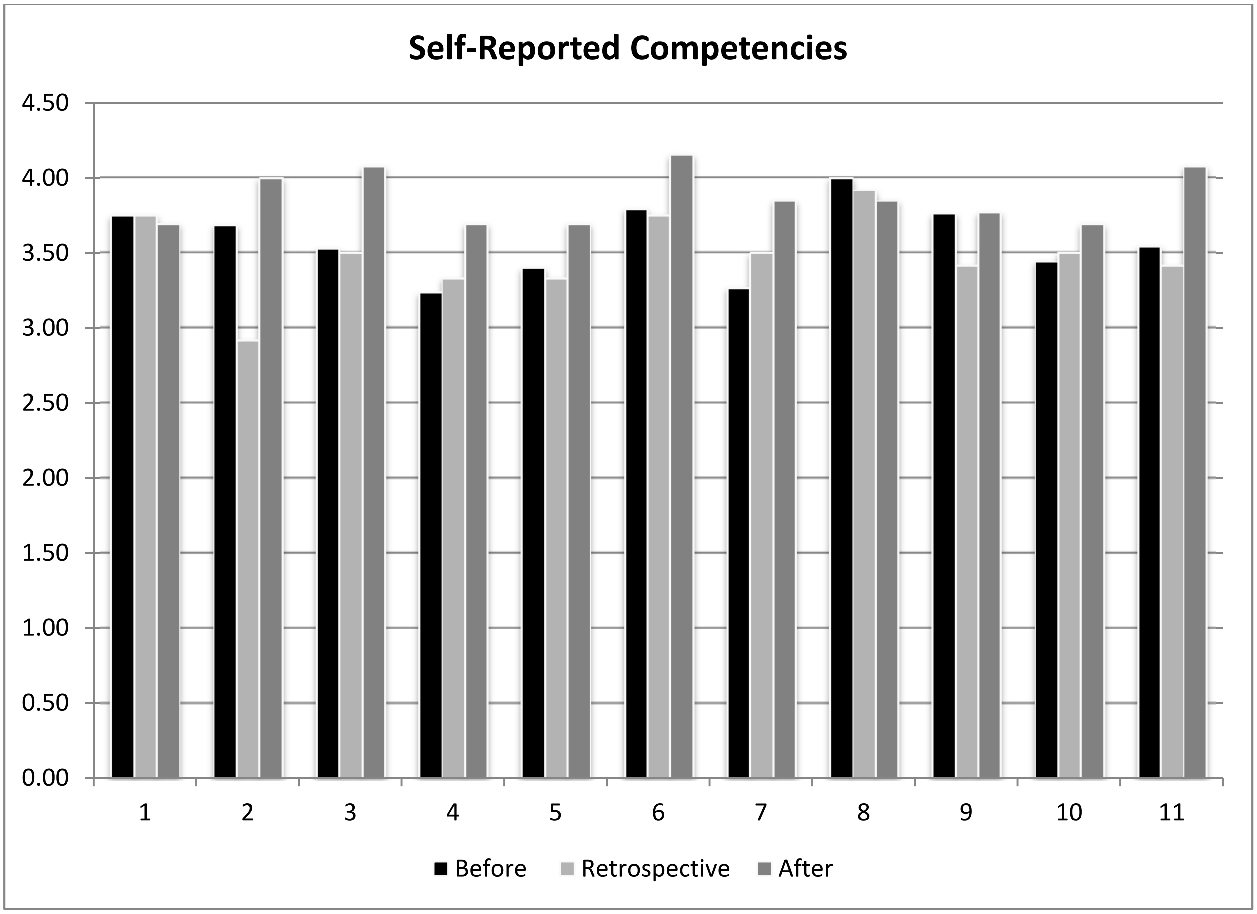

Figure 16: Average confidence rating from self assessment surveys. Questions are found in Table Y. "Before" questions were from the beginning of semester survey. "After" and "retrospective" questions were from end of semester self assessment.

Mentee Draw an Engineer Test

The Draw an Engineer Test was very successful in tracking changes in mentees' attitudes to and preconceptions towards engineering throughout from the beginning to the end of the semester. Initially, mentees had little idea what engineers actually did, and consequently drew pictures of the stereotypical construction worker, auto mechanic, and mad scientist. By the end of the semester, although some stereotypical elements remained, the responses from the students were more diverse, consisting of astronauts, robotics engineers, and chemists. On one occasion the mentee drew himself planning a blueprint, showing that he believed engineering is not limited to adults, but can be done by children as well.

Many of the ideas of our mentees in the "after" activity were directly related to our lessons and activities. This indicates that our lessons had a large impact on their perceptions of engineering and science, but also that they are not being exposed to these ideas elsewhere. There is great potential to introduce students to new fields and applications of engineering in their community.

Figure 17: DAET "Before". Note the stereotypical presentations of the engineer and scientist.

Figure 18: DAET "After". One student draws a "scientist" closer to her phenotype. Another draws a "car of the future."

Final Projects

The final presentations were given at a semi-formal event called the BEAM Mini-Conference. It was clear that the additional effort required for this final project and presentation created a sense of pride and ownership in the mentors. It also helped them to take ownership of the semester long relationships they developed with their mentees.

Moreover, mentors developed effective and novel assessment tools for their mentees. Mentors noted that written tests were counterproductive to engaging mentee participation. One mentor group created a simple worksheet where mentees were asked to match the lesson plan to the scientific/engineering concept that it dealt with. 79 percent of the mentees had zero wrong answers and 21 percent of them had one wrong answer.

All project groups gave an evaluation of the entire BEAM semester at their sites, explaining the successful methods, the areas of improvement, and recommendations for improvements. The final project provides an effective means of assessing mentors and gathers new ideas for improving the program.

Lastly, many of the final projects also emphasized iteration of the design process, which is rarely done in classes today. This demonstrates that the mentors engaged in the top four tiers of Bloom's Taxonomy (Apply, Analyze, Evaluate, and Create). The process of making lesson plans forced students to utilize these upper levels because it encouraged them to understand the concepts, evaluate what was important, and teach the material in a novel way. While mentors were not actively exposed to Bloom's Taxonomy, the principles that govern it were incorporated in the thought processes of the mentors.

Summary and Future Work

BEAM is unique amongst engineering outreach efforts in that it is designed, implemented, and led entirely by students. Our mission has grown to encompass leadership development as an equally important goal next to mentorship. Our leadership structure encourages mentors to take initiative and responsibility early on.

BEAM is a data-driven organization. Every activity is coupled with a novel assessment tool to gauge its impact. An evaluation by our mentors showed that they benefited personally from taking the class. Mentors particularly cited their ability to lead, think creatively, and recognize the broader impact of engineering. Our mentees showed notable changes in their conceptions about engineering and science, made visible through the Draw an Engineer Test.

Future Work

In the near future, BEAM intends to collect more quantitative data from both the mentors and mentees through surveys and worksheets. Additionally, we hope to obtain data from outside sources such as the parents of mentees and schools. This will better enable BEAM to determine where its program excels and where it can improve.

Every year, new partnerships are being formed with new schools and other universities, extending BEAM's impact outside our local community. One of the goals for the future is to make all the lesson plans, worksheets, and other resources publicly available. Currently, in order to achieve this, a central BEAM website is used to archive all the lesson plans from the past. Work is already being done to further improve the searchability of the lesson plans as well as to collect comments and criticism from other teachers on aspects of the lesson plan that worked particularly well or could be improved. By effectively packaging the BEAM model and resources into one location, we hope to facilitate BEAM's growth to other engineering schools throughout the country.

Another goal of BEAM is to integrate the program into the university's core engineering program. As supported by our assessments, BEAM improves the mentors' problem solving abilities and gives them the chance to teach one another, thus reinforcing theoretical class material. In a further effort to integrate engineering and outreach, mentors will also work with faculty to design their lesson plans for the final project, incorporating cutting-edge research projects into elementary lessons. Another possible effort is to design a separate mentoring and teaching class for upper division BEAM students that can serve as a thesis course. Students taking this course would design and test novel lesson plans and teaching methods to help shape future BEAM efforts.

Acknowledgements

We would like to thank our advisor for supporting the organization and getting it started. We would also like to thank our mentoring professors who have dedicated their time and expertise in teaching us how to teach effectively, the after school directors for providing us with a place to teach, as well as our community partners for providing us with funds, materials, and a location for our mentor training workshop. And finally, we would like to thank the rest of the BEAM staff for devoting their time efforts to make BEAM a success.

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An Aerospace Engineering Summer Camp for High School Students

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Abstract

A summer camp for high school students has been held at Embry-Riddle Aeronautical University in Prescott, Arizona for the past six summers as a way to expose students to the concepts and the practice of aerospace engineering. This intensive one-week camp immerses students in aspects of aircraft and spacecraft engineering, where the students alternate between lectures, computer simulations, and hands-on laboratory demonstrations and projects. Topics include aerospace propulsion, astrodynamics, aerodynamics, stability and control of aircraft and spacecraft, structures and materials, and computer-aided design (CAD). Each of these topics includes either computer or traditional laboratory components to keep the students engaged. Some examples of the accompanying hands-on work include the design and construction of balsa wood gliders following the lecture on aerodynamics, and the designing of truss bridges using CAD tools, which are subsequently formed from ABS plastic using a rapid-prototyping printer. These particular activities end with a friendly competition between students using both their balsa glider, flown for maximum glide distance, and the fabricated bridge, tested for maximum strength-to-weight using a hydraulic load frame in the mechanical testing laboratory. This paper provides details of the academics, enrollments, and student evaluations of the Aerospace Engineering Summer Camp.

Introduction

The Prescott, Arizona campus of Embry-Riddle Aeronautical University (ERAU) specializes in undergraduate education, with a current enrollment of close to 1700 students. The College of Engineering houses the largest department at the campus, the Aerospace and Mechanical Engineering Department. The engineering student body is composed exclusively of undergraduate students. The department strives to provide close student-faculty instruction and mentorship, significant design experiences, and a hands-on learning environment.

The Prescott campus has been developed with undergraduate education in mind, and laboratories with extensive space in which students can work are a feature. While some number of summer courses is taught, especially during the first summer term, many classrooms and laboratories are nevertheless underutilized when compared to the regular academic year. Embry-Riddle, therefore, likes to provide summer programs for a wide variety of activities, especially those with an academic flavor (which, of course, serves our university mission). Further, the summer climate in Prescott, which is at an elevation around 5300 feet above sea level, makes ERAU an attractive location for summer activities in the state of Arizona.

There is a desire to provide opportunities to get high school students interested in STEM (science, technology, engineering, and mathematics) fields, which is often not done well in K-12 grades, especially when many school districts have financial challenges to contend with. Embry-Riddle is a small, technically-oriented private university in central Arizona, and is interested in both raising the profile of STEM-related degree programs and, of course, offering attractive summer programs at our campus that help recruit new students. The Aerospace and Mechanical Engineering Department is particularly supportive of hands-on learning experiences, and has worked to develop extensive laboratory facilities for the undergraduate engineering programs[1].

Prescott Campus Summer Programs

During the 2010 summer, three summer academic programs were offered by Embry-Riddle faculty in aerospace engineering, flight, and computer engineering. Each program is intended for high school students from ages 15 to 18 (14 to 18 for the flight program), is one week in duration, and involves students in classroom, laboratory, and a few evening non-academic activities. Table 1 provides a very brief introduction to the three programs.

Table 1. Summer Programs Overview (from Summer of 2010)

Program	**Topics and activities**
Aerospace Engineering	Introductory lectures accompanied by hands-on laboratory and design experiences in flight and space sciences, structural design and material properties. Balsa wood glider and bridge design competitions.
Computer Engineering	Introductory lectures on robotics and machine vision. Hand-on programming and machine vision system design.
Flight Exploration	Instruction on weather reports and visual flight rules (VFR), as well as aerodynamics, navigation performance, and safety procedures. Students do fly aircraft during the program!

Outside of the academics, students spend the week staying at the campus in the dorms, eating meals at the cafeteria, and participating in social activities. The sum of all these parts leads to a short one-week introduction to college life, which may have some benefits to the high school students if this is viewed from a student retention aspect. The student registration costs for the Aerospace Engineering and Computer Engineering programs was $1050 for the 2010 summer, which covered meals, lodging, and instructional materials. The registration cost per student for the Flight Exploration program was $1950 for the 2010 summer, and this additionally included flight fees, which is a significant cost. The registration fees for the 2011 summer will remain the same.

A number of Embry-Riddle students are hired for the week to act as mentors and chaperones to the high school students, and they answer questions and make sure the summer camp students get to where they are supposed to be. Faculty and staff serve as the instructors, and lead the summer camp students in classroom discussions and hands-on work. The Aerospace Engineering summer camp was the first summer camp (Summer 2005) to be offered at the Prescott campus of Embry-Riddle, and the others were added in subsequent years.

Aerospace engineering camp

The Aerospace Engineering program has had great success in its current form. The last four summer enrollments for only the Aerospace Engineering program are given in Table 2. During the first four years, just one class of up to 24 seats was offered, and that was increased to two concurrent classes during the last two summers. Each class has been filled to capacity each summer, and is typically held mid-summer in late June or early July. It is further noteworthy that while engineering camps for high school students are held at other universities, it is believed that ERAU holds the only such camp exclusively for aerospace engineering in the country.

Table 2. Enrollments in Aerospace Engineering Summer Program

Summer	Enrollment
2006	24
2007	24
2008	24
2009	48
2010	48

An additional third section was added this past summer (2010) because of the popularity of the program. However, due to a faculty member leaving from the computer engineering department and the small number of students (around 5) enrolled for the Aerospace Engineering program, students from the third section were placed into a more general engineering camp, not reflected in the numbers in Table 2.

Participating instructors in the Aerospace Engineering summer camp are all faculty in the Aerospace and Mechanical Engineering Department at Embry-Riddle. A number of these faculty teach undergraduate engineering courses during the first seven-week summer semester, so there are enough instructors that spend their summers in the Prescott area to make adequate commitments to help teach at the summer camp. These high school student summer camps are typically scheduled to closely follow the early-summer semester for the convenience of faculty scheduling.

The instructors each present topics in their respective disciplines of interest, with a total involvement of five to six instructors. Figures 1 and 2 provide the two schedules from the 2010 summer semester.

Breakfast	Breakfast	Breakfast	Breakfast	Breakfast
7:15am-8:00am	7:15am-8:00am	7:15am-8:00am	7:15am-8:00am	7:15am-8:00am
EagleCard 8:00am	Astrodynamics	Structures	Aerodynamics	
Propulsion	8:00am-9:00am	and Materials	8:00am-10:30am	Glider Competition

8:30am-10:00am	Space Lab 1a	8:00am-10:30am		
	(SIMULINK)			
Propulsion Lab	9:00am-11:00pm			Bridge Competition
10:00am-12:30pm		Materials Lab	Wind Tunnel Lab	
	Space Lab 1b (STK)	10:30am-12:00pm	10:30am-12:00pm	Lab Tour
	11:00am-12:00pm			
	Lunch	Lunch	Lunch	Graduation Lunch
Lunch	12:00pm-1:00pm	12:00pm-1:00pm	12:00pm-1:00pm	Visitors Center
12:30pm-1:30pm	Space Lab 1b (STK)	Solid Works	Stability and Control	12:00pm-1:30pm
Applied Controls	1:00pm-2:00pm	1:00pm-3:00pm	1:00pm-3:00pm	
1:30pm-3:00pm	Space Lab 2			
	(EyasSat)			
Controls Lab	2:00pm-4:30pm	Solid Works	Glider Design Lab	
3:00pm-5:30pm		Bridge Design	3:00pm-5:30pm	
		3:00pm-5:00pm		
	Dinner			
	4:30pm-5:30pm	Dinner		
Dinner	Admissions	5:00pm-6:00pm	Pool/Ramada	
5:30pm-6:30pm	5:30pm-6:30pm	Sand Volleyball	5:30pm-7:30pm	
Capture the Flag	ROTC	6:00pm-8:00pm		
6:30pm-8:00pm	6:30pm-7:30pm			
			Packing and Eval	
			7:30pm-8:30pm	
		Satellite T&O	Satellite T&O	
		8:30pm-10:00pm	Backup date	

Figure 1. Schedule for students in "Alpha" section of Aerospace Engineering program.

The first schedule was for the student group referred to as "Alpha" group, and the second for the "Bravo" group, and these schedules are typical of the aerospace engineering summer camps from past summers. The schedules are always quite packed to keep the students busy Sunday evening (not shown) through early Friday afternoon. Monday through Thursday, the students are involved in academics with introductions to the topics of propulsion, flight and space controls, astrodynamics, structures and materials, aerodynamics, and aircraft stability and control. Each topic is accompanied by a hands-on activity or laboratory experience to better show the application of theory to engineering practice. The aerodynamics discussion was followed by an opportunity for students to have some involvement with one of the wind tunnels at ERAU. The students built a balsa wood glider, using some of the knowledge obtained from the aircraft stability and control discussion, and this was concluded with a glider competition among the students, who worked in small groups.

Breakfast 7:15am-8:00am	Breakfast 7:15am-8:00am	Breakfast 7:15am-8:00am	Breakfast 7:15am-8:00am	Breakfast 7:15am-8:00am
EagleCard 8:00am	Propulsion 8:30am-10:00am	Astrodynamics 8:00am-9:00am	Aerodynamics 8:00am-10:30am	Glider Competition
Structures and Materials 8:30am-11:00am	Propulsion Lab 10:00am-12:30pm	Space Lab 1a (SIMULINK) 9:00am-11:00pm	Wind Tunnel Lab 10:30am-12:00pm	Bridge Competition
Materials Lab 10:30am-12:00pm	Lunch 12:00pm-1:00pm	Space Lab 1b (STK) 11:00am-12:00pm	Lunch 12:00pm-1:00pm	Lab Tour
Lunch 12:30pm-1:30pm	Applied Controls 1:00pm-2:30pm	Lunch 12:00pm-1:00pm	Stability and Control 1:00pm-3:00pm	Graduation Lunch Visitors Center 12:00pm-1:30pm
Solid Works 1:30pm-3:30pm	Controls Lab 2:30pm-5:00pm	Space Lab 1b (STK) 1:00pm-2:00pm	Glider Design Lab 3:00pm-5:30pm	
Solid Works Bridge Design 3:30pm-5:30pm	Dinner	Space Lab 2 (EyasSat) 2:00pm-4:30pm		
		Dinner 4:30pm-5:30pm		

Dinner	5:00pm-6:00pm	Admissions	Pool/Ramada
5:30pm-6:30pm	Sand Volleyball	5:30pm-6:30pm	5:30pm-8:00pm
Capture the Flag	6:00pm-8:00pm	ROTC	
6:30pm-8:00pm		6:30pm-7:30pm	
			Packing and Eval
			7:30pm-8:30pm
		Satellite T&O	Satellite T&O
		8:30pm-10:00pm	Backup date

Figure 2. Schedule for students in "Bravo" section of Aerospace Engineering program.

Another opportunity for students to put theory into practice was through a bridge-building competition. Following the discussion on structures, the students participated in a computer lab using SolidWorks, where students learned some three-dimensional modeling techniques, with time to complete a 3-D drawing of a truss bridge. Students performed this final exercise in small groups. The SolidWorks files were then given to an Embry-Riddle student assistant who had the bridges fabricated in ABS plastic using the 3-D printers at Embry-Riddle (Embry-Riddle has two Stratasys Dimension SST 3-D printers). Finally, on a following day, the bridges were tested for structural efficiency (failure strength divided by weight) using an MTS 810 hydraulic load frame in the Embry-Riddle mechanical testing laboratory.

One of the authors first became involved directly in the summer camp through work on an NSF (National Science Foundation) CCLI (Course, Curriculum, and Laboratory Improvement) grant[2]. This grant was for the creation of an undergraduate laboratory-based course in engineering failure (although the grant was not for any direct funding of this summer camp). The author committed to bring a small portion of the topic of materials failure to the summer camp, taught the section on materials, and with one of the other authors, had students perform tension tests on aluminum dogbone samples, section and ultrasonically clean one end of the broken pieces, and then view the fracture surfaces with a scanning electron microscope (SEM). A handout on the SEM was provided to the students, and the digital photographs of the fracture surfaces were made available electronically.

Since the addition of a second section of the Aerospace Engineering program, scheduling has become a little trickier, but was accomplished by staggering the various topics. Viewing Figures 1 and 2, one can see how this staggering was accomplished. One complication is the schedules of the instructors, who may be teaching summer courses. The other noteworthy complication is in scheduling the structures discussion and the ensuing bridge design. The bridge CAD models are all fabricated using the two 3-D printers, and the process is somewhat time consuming. Having either of the Solid Works computer modeling sessions on Thursday would not be an option for this reason, and in case of unforeseen 3-D printing problems, is it perhaps necessary to have these portions of the summer program as early in the week as possible. Also, in the program's current form, this might easily be a limitation on trying to have three student classes all at the same week (among other possible scheduling difficulties).

Student Evaluation

The office for Summer Programs at the Prescott campus of Embry-Riddle conducts student surveys after each summer camp. The survey questions are fairly general, and encompass both the academics as well as the housing/meals/extracurricular portions of the program. The survey for the 2010 summer camp, performed using SurveyMonkey, included question such as:

1. Please rate your overall satisfaction with the Aerospace Engineering Program. Please provide any additional comments you may have below. This allows us to improve camp in the future.
    a. Overall satisfaction (1-10 satisfaction rating)
    b. Quality of Instruction (1-10 satisfaction rating)
    c. Relevance of Classes (1-10 satisfaction rating)

Such questions were given on the dining and residence hall experiences, with some survey questions on specific extra-curricular activities. Questions on the interest and satisfaction on the specific aerospace topics were included.

Regarding the academics, it was found that students showed slightly more interest in the aerodynamics-type topics (and especially the rocket-launch), and a just little less interest in astrodynamics, structures, and materials. However, student satisfaction was high for all topics. Students were also encouraged to provide written comments, and they indeed provided many, which probably provide more insight that the numerical ratings. While comments ranged widely on all sorts of relevant (and sometimes not especially relevant) topics, one recurring theme was that many students enjoy and would like to see more of the hands-on work and laboratory experiences, compared to the amount of time spent on the classroom lectures and discussions. The amount of time in lectures and discussions can be viewed in Figs. 1 and 2 from the yellow boxes during the first four days (noting that there is often a 15-minute break in the middle of the longer classes), and the hands-on and laboratory sessions are boxed in white. There is somewhat more time devoted to the latter, and the instructors are reluctant to give up much more of the lecture and discussion time. However, one of the authors previously noted that the SolidWorks sessions end up being a little rushed in the completion of the bridge design, because there is certainly a learning curve necessary to end up with workable CAD file, ready for the 3-D printer, and this fact was also reflected in a few comments. An Embry-Riddle student assistant now helps out with this activity, to make sure that students have their files ready to go, and further, this student assistant may also fix the CAD files somewhat if necessary, to ensure proper 3-D printing.

Additional details

The summer camps are advertised nationally by ERAU, and therefore the states of residence claimed by the students vary widely, as shown in Table 3 (only incomplete data for more recent summers were available to the authors at the time of writing, so just 2006 and 2007 are shown). Only a few students come from the immediate Prescott, Arizona area. In the most recent summers, including the upcoming 2011 summer, a few international students have enrolled, which is useful for increasing international exposure for ERAU.

Table 3. Enrollments by state of residence

Summer	Student states of residence
2006	AZ (8), CA (8), FL (2), NV (1), NY (1), OH (1), OR (1), TX (1), VA (1)
2007	AZ (4), CA (6), CO (2), FL (2), HI (1), MA (1), MN (1), NC (1), NJ (1), TN (1), TX (2), WI (1)

The largest fraction of summer camp students, somewhere around half, tend to be high school juniors. The remaining students are of somewhat similar fractions of freshmen, sophomores, and seniors. Table 4 shows additional enrollment information regarding the high school camp students. The number of female students is unfortunately low, with the fraction of female to males remaining about the same from 2006 to 2010. However, the increase in total number of aerospace engineering students at the camp has led to a greater number of females being exposed to this STEM program.

Table 4. Details of enrollments in Aerospace Engineering Summer Program

Summer	Camp Enrollment	Female students	ERAU applicants*	Matriculated to ERAU*
2006	24	5	9	7 (1 at DB)
2007	24	3	15	9 (2 at DB)
2008	24	5	13	5
2009	48	9	16	4 (1 at DB)
2010	48	8	2	2

*as of August 2010

Embry-Riddle is also certainly interested in encouraging summer camp students to consider enrolling at the university as an undergraduate. The number of applications submitted by the aerospace engineering summer camp students is shown in Table 4, as of August 2010. Of course, any high school student who attended the 2010 summer camp and was of junior or earlier standing, would not have submitted an application by the time of this writing. Therefore, the earlier years of the summer camp provide more thorough information on how this program affects students' choice to apply to ERAU. Finally, the number of students matriculating to Embry-Riddle is shown in the last column of Table 4. A few of these students enrolled at the Daytona Beach residential campus of Embry-Riddle, and this number, out of the total number matriculating to ERAU, is noted in this column. At least one of these latter matriculations ended up in a reported no-show when it came time for students to arrive on campus for the beginning of the Autumn 2010 semester, however, illustrating one of the possible difficulties in maintaining accurate statistics. Overall, this summer camp, as well as the others offered by ERAU (statistics not shown), appear to have a positive effect on undergraduate enrollments.

Summary

The summer camps at Embry-Riddle Aeronautical University in Prescott, Arizona have become a strong addition to the growing range of offerings made available to those interested in technical fields of learning. Student satisfaction is high with the current form of the Aerospace Engineering summer camp program, and the instructors are dedicated to bringing a strong, positive experience to the high school students, with the aim of generating interest in STEM-related opportunities. The summer programs also

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Biography

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Student Usage and Assessments of the Benefits of On-Line Access to Lecture Recordings with Synchronized Presentation Slides

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Abstract

Students in multiple sections of an introductory Digital Design course were provided with on-line access to recordings of every class lecture. These recordings were made using the Panopto Coursecast tools, and included live audio recordings of the instructor along with video capture of compressed still image representations for each presentation slide shown. The audio and slide changes were captured concurrently and in real-time so that during replay students experienced the complete presentation very similarly to how it was originally delivered. Since the lecture recordings did not include full live video capture, the data storage and connection bandwidth requirements were minimized. Anonymous student surveys at the end of the quarter indicated that a large majority of students found this to be a very helpful tool and would prefer to have this tool available for other classes as well. Reported usage rates and purposes varied widely between students; ranging from no use at all, to occasional replay of short excerpts to clarify segments that were not clearly understood during the lecture, to complete replay of most lectures as a study aid in preparation for midterm or final exams. While many students assessed the most helpful benefit of on-line lecture captures to be the ability to make up a missed lecture, most also self-reported that having this available did not diminish their attendance at lectures. Student comments revealed that they recognized the superiority of the live lecture experience compared to the captured lectures. Probable contributors to this impression include the inability to see anything written on the blackboard in the on-line presentations, the loss of some slide animation features, the inability to see the instructor's gestures and pointing to slide highlights, and the partial loss of student comments, questions, and interactions in the audio recordings

Introduction

Lecture capture, the recording of face-to-face classroom lectures in digital format, and making these recordings available for asynchronous first-time viewing or reviewing by students, is an important and beneficial tool for engineering education that has been in use for several years now; but that has experienced a slow adoption rate. In the 2010 National Survey of Information Technology in Higher Education[1], a survey of senior campus information technology officers from 523 public and private colleges and universities across the United States, more than sixty percent of the survey participants either "agree" or "strongly agree" that lecture capture is an important part of their plans for developing and delivering instructional materials. However, this technology is not yet very widely deployed. According to this same survey, as of fall 2010, only 4.4 percent of higher education classes make use of lecture capture technology.

In the study presented here, the impressions of students using one such lecture capture tool suite in an electrical engineering digital design class were collected using a post-class written survey tool. The survey sought to quantify the number and duration of on-line lecture viewing by students, as well as their impressions of the helpfulness of the tools in achieving several potential benefits for the course, from the point of view of students using the tools. Since these tools are not widely used, the experiences captured here are likely the first experiences that students would have had with this supplemental learning technology.

Lecture Capture Tool

The lecture capture tool used in this study was Panopto Coursecast - a software-based presentation capture system originally developed at Carnegie Mellon University. Using this tool on their own laptop computers, instructors record any content displayed on their screen, such as Powerpoint slides, as well as an audio channel and an optional video stream from a web cam or other video source attached to their computer. These streams are integrated into a narrated presentation video that can then be uploaded to a server and shared with students online. Once uploaded, students can view captured lectures using standard web browsers supplemented with the Microsoft Silverlight plug-in. Panopto integrates with both Blackboard and Moodle, allowing captured lectures to be accessed by students through the same courseware system interface they already use for their classes. Students can also download the lecture audio from the server in .mp3 format.

For the instructor, recording a lecture with Panopto simply requires them to start up the Recorder application on the computer from which they will be presenting, and then select the audio and video sources that are to be captured. For digital presentation content, the instructor must select whether compressed images of their Powerpoint slides will be captured or if snapshots of their screen will be encoded periodically. For Powerpoint slides, the Recorder captures a new image of the slide whenever the presentation is advanced by the instructor or by an animation sequence. For periodic screen encoding, the frame rate at which new images are captured is set by the user for between 1 to 15 frames per second. The capture frame rate greatly affects the loading on the presentation computer's CPU. Choosing too high a frame encoding rate can interfere with the instructor's presentation, slowing down slide advances and animations.

For the lectures in this study, Powerpoint slide image capture was selected for all videos created, as the higher frame rate encoding of screen snapshots did, in fact, severely interfere with the projected Powerpoint presentations due to the limited computational capability of the instructor's laptop computer. No additional video input was used for the recordings, to minimize the server storage file size and required playback bit rate of the resulting lecture capture video. Therefore, only the Powerpoint slide content was viewed by students in the captured lectures. The gestures of the instructor and any exposition on the classroom white boards were not recorded. With these recording selections, the video produced by Panopto included an image of the currently displayed Powerpoint slide, a window with preview thumbnails of a few slides preceding and following the current slide, a window with time stamps and slide titles for each new slide in the presentation, and a synchronized audio track providing the same narration that occurred during the original lecture presentation.

Using the slide capture mode instead of higher rate screen captures had several consequences for the rendering of Powerpoint animation sequences in the final video. While smooth motion animations played properly during the projected presentations, most of the motions were lost in the recorded versions. This is because a new slide image would be captured only at the end of each animation step. On playback then, animations would appear somewhat disjointed. Also, the recording of a new slide image with each animation step resulted in many slightly changing copies of each Powerpoint slide appearing in the timestamp and slide preview windows of the recording. This made searching and forwarding in the captured lecture a little more cumbersome for students.

The audio stream for the recordings was captured from a USB wireless microphone worn by the instructor. The directional microphone provided a clear recording of the instructor's voice. However, it was unable to clearly pick up comments and questions from students during the lecture.

For playback of the captured lectures, students were provided a simple link from Blackboard to a listing of all the available lectures. Clicking on a particular lecture opened the Panopto recording in a new browser window. The recorded lecture would automatically begin playback. Students could pause and stop the playback at any time. Using the slide thumbnail preview window or the slide timestamp window, students could advance or rewind to any particular slide in the presentation. Therefore, they could view as much or as little of the captured lecture as needed – from simply checking one or two slides to be sure they completed their notes properly, to seeing and hearing the entire lecture for a second time.

Course Design

Lecture capture was incorporated into a ten-week introductory Digital Logic Design class (CPE 129) as part of a pilot program to evaluate the Panopto Coursecast tools for possible broader deployment at California Polytechnic State University. This class is the first in a series of three digital circuit and computer design courses required in both the electrical engineering and computer engineering bachelor of science degree programs at CalPoly. In these degree program curriculum sequences, this class is typically taken in the spring quarter of the freshman year for electrical engineering students, and in the fall quarter of the sophomore year for computer engineering students. The course is structured with three fifty minute lecture classes each week and has an associated laboratory course that meets once a week for three hours. In this structure, design and analysis methodologies for digital circuits are introduced and developed in the lecture classes, and students then implement and practice these methods using computer-aided design tools in the laboratory sessions. Typically, between thirty-two and forty eight students are enrolled in each lecture class section. Lecture classes are conducted in traditional classrooms that include digital projectors and screens, as well as chalkboards or whiteboards. Depending on the academic quarter and holiday schedules, the total number of lecture classes for the course varies between 28 to 30 sessions. As with all CalPoly courses, students access all on-line content for this class using the Blackboard learning management environment.

The lecture presentations used in the course sections surveyed for this study were almost entirely rendered using Powerpoint. Only occasionally were concepts elaborated or examples worked out using the classroom white boards. This was important for compatibility with lecture capture, as these elaborations would not appear in the lecture recordings. The Powerpoint presentations for the class were somewhat unique, in that they made extensive use of graphics and animation to illustrate the information and methods being taught. Careful attention was placed on revealing information in each slide at the moment that it was presented, so that students both in the classroom and on-line would not be overwhelmed with too much information at once. Because of the complexity of the graphics presented, the volume of material covered, and the pace of the course, students were provided with copies of the lecture slides as handouts at the start of the class session. These handouts were also made available on-line as PDF files, so that students who missed a live lecture could use the handouts when viewing the lecture on-line. Course handouts included most of the information projected onto the screen during the lecture. However, key terms and example problem steps were left out so that students would have to actively engage with the lecture, whether viewed live or on-line, and reinforce their learning by writing notes on the handouts.

Students are expected to attend all face-to-face lecture classes. This is not compulsory, however, and classroom attendance was not monitored or incorporated into the course grade computation for this class. Grading was based primarily on each student's performance on two midterm examinations and the final examination. A portion of the course grade (20%) was based on the completion of homework assignments and graded projects. Homework was assigned after every lecture class, which was due at the next class session. This required students to keep up with the course pace, and to assimilate and practice each lecture's material shortly after hearing it.

Study Survey Methodology

The data for this study were collected using a written survey administered at the end of the CPE 129 course. The survey was conducted in three different academic quarters with students from a total of six lecture class sections (two sections in June 2010, three sections in June 2009, and one section in March 2009). The survey was provided to students online via Blackboard following their final lecture class. Students were asked to return the completed survey in hardcopy form at their final examination session; generally three to five days after the request for their participation. The surveys were anonymous, other than answers to two demographic questions - year in school and degree program. As an incentive to increase the participation rate in the survey, two bonus points on the final examination were awarded to students who turned in a survey paper. This was also intended to broaden the participation to include those students who might not otherwise take the time to complete a survey that had no direct effect on them. Anonymity was maintained and redundancy of responses was prevented by having students check off their names from a class roster when turning in a survey sheet. Students turned in surveys in a random order when they arrived at the final examination. The large number of surveys returned and the relatively high participation rate maintained anonymity to the satisfaction of the students; despite there being a record that they had each turned in a survey. Of the two hundred twenty eight students in the five sections surveyed, one hundred and forty provided survey responses (61% participation).

Survey questions queried students about the number of times they accessed the on-line lectures, how much of each lecture they typically viewed, how helpful the on-line lectures were in achieving several delineated potential benefits, and whether they preferred to take courses in the future with lecture capture. All answers, including quantitative ones regarding number to times used and viewing durations, were based on student's recollections, rather than objective measurements.

Survey Subjects

Students who took the survey were predominantly electrical engineering majors, with a small number of computer engineering students and computer science students. Sixty eight percent (95 of the 140 students) were college freshmen. Of the remaining students, 23 percent were sophomores, seven percent considered themselves to be juniors and two percent were seniors (4^{th} year students). Typically, junior and senior (3^{rd} and 4^{th} year) students would not take the CPE 129 course surveyed. However, transfer students who arrive after two years of community college start the EE curriculum at the beginning of the sophomore year in the degree program, despite being "3^{rd}" year students (Juniors). Therefore, for transfer students, taking CPE 129 in their first year at CalPoly is appropriate.

Survey Results - Student Usage Rates of On-Line Lectures

Students were first asked if they used the Panopto system at all to view on-line course lectures during the quarter. Eighty-one percent of students responding (113 of 140) indicated that they had used the system at least once. Compared to the twenty eight total lecture capture videos available to students, 5.8 was the average number of lecture viewings reported per person for all respondents. This number increased to an average of eight lectures viewed when considering only those students who had accessed the system at all. Figure 19 shows the histogram breakdown of the number of lecture views reported by all students.

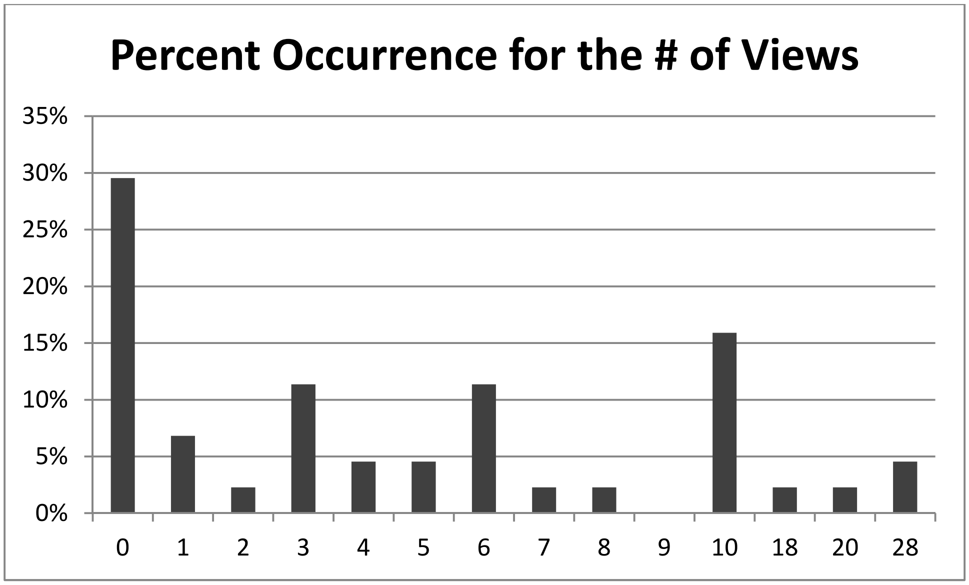

Figure 19. Occurrence percentage for each reported number of lecture views for all survey participants

To determine what portion of each lecture students were viewing on-line, the survey asked students first to report the average number of minutes viewed for each lecture accessed. For those students who used the on-line lecture viewing at all, the average viewing time was just over half of a standard lecture (26.6 minutes average viewing time reported). Students were then asked to divide their total number of viewing times into categories of "less than 5 minutes", "¼ to ½ of the lecture" (12-25 minutes), "more than ½ of the lecture", or "most/all of the lecture." Figure 20 shows the resulting histogram of reported viewing times by students.

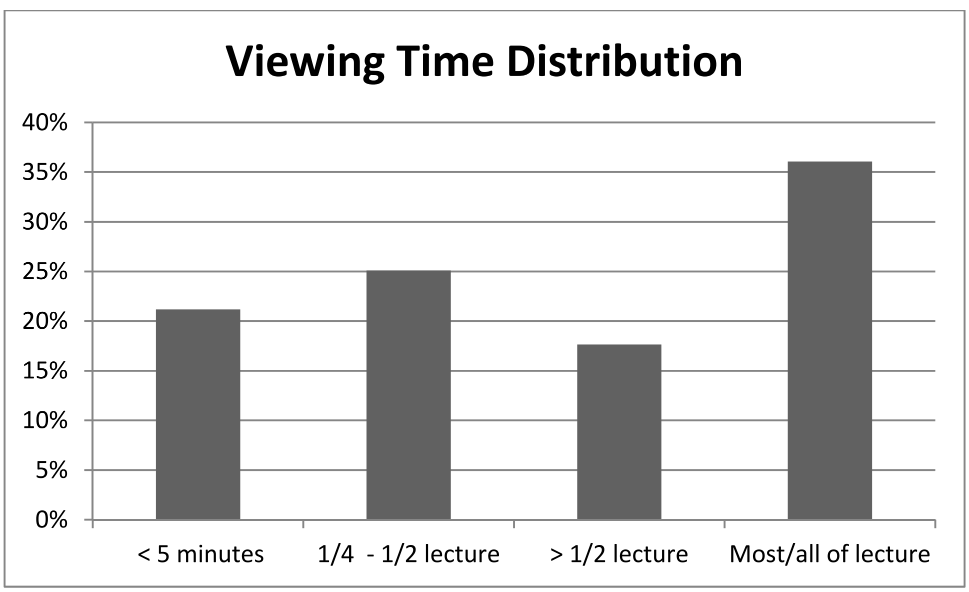

Figure 20. Viewing time distribution of on-line lectures reported by students in CPE 129 Digital Design.

These results indicate that students were likely using the on-line lectures for a number of different reasons, rather than for one single purpose. A brief reference to a short segment (< 5 minutes), such as to check or complete lecture notes or to review one concept, was sufficient for one-fifth of the students. Viewing most or all of a lecture, possibly to make up for a missed class or to review for an examination, was the most reported viewing duration.

Student assessment of potential lecture capture benefits

The survey presented students with several potential benefits of on-line lecture recordings, and asked them to assess how helpful they found this tool in achieving these benefits in our particular course. Students assessed the helpfulness of lecture capture using a 1 to 4 scale, with 1 = not at all helpful, 2 = nice but not necessary, 3 = somewhat helped learning, 4 = very helpful / big improvement in learning.

The average ratings for each of the benefits proposed, by students who viewed at least one lecture capture were:

- Making up for a missed class – 3.36
- Clarifying information or finishing notes from a prior class – 3.35
- Improving retention of class materials – 3.07
- Reviewing material before class – 2.93
- Improving test scores – 2.77

Students found the ability to view the lecture from a missed class or to review information and clarifying their understanding of the presented lecture material as the most helpful benefits of on-line lectures. While several individual students made specific written comments around using the on-line lectures to review for examinations, overall students did not find it to be as helpful for that purpose as for the other proposed benefits. These ratings also indicate that students generally found lecture captures to be at least somewhat helpful and effective for all the potential benefits.

When asked the broad question of "did lecture capture help you succeed in this course?", 75 percent of students said "Yes". The remaining 25 percent were made up mostly of students who had not used the tools at all (20%), and 5 percent of students who actually used the tool at least once but still assessed that it did not aid their success.

Finally, to gauge their overall satisfaction with lecture capture, students were asked if they had a choice between taking a course with or without lecture capture in the future, which would they prefer? Fully 95 percent of students indicated they would prefer to have lecture capture available. The remaining 5 percent indicated that either it did not matter to them or that they preferred not to have lecture capture. The written comments as to why students preferred to have lecture capture echoed their ratings of the potential benefits. Being able to see missed class lectures and to review and clarify course material were again the most cited reasons for preferring that lecture capture be available. Even those student who were generally less enthusiastic about the tool in their usage or ratings of benefits felt that it was still helpful to have lecture captures in future courses "just in case."

Effect of recorded lecture availability on class attendance

One concern with providing on-line lecture recordings commonly voiced by instructors[2] is that it might encourage students to stop attending classes, or to at least diminish their attendance significantly. Indeed, the attribute of on-line and hybrid courses most highly appreciated by students is the scheduling flexibility they afford, as lectures can be viewed whenever it is most convenient for students. Therefore, instructors question whether students will take advantage of recorded lectures intended as supplemental course material, and treat the course instead as an on-line class and stop attending live lecture sessions. By this line of thinking, students might at least take a more casual approach to class attendance, as a more convenient alternative is provided to them in the recorded lectures. Thus, any provocation not to attend a class might be sufficient to convince students that it is not necessary to do so.

Students in the present survey were queried about this issue. In the survey, students were asked "what effect, if any, did having on-line lectures have on your class attendance?" Ninety-three percent of students (130 out of 140) indicated that there was no effect at all on their attendance. Just under six percent (8 out of 140) indicated that they skipped one or two additional lectures than they might otherwise have if lecture capture was not available. Two additional students (1.4%), one senior and one sophomore, responded that they skipped three or more additional lectures. Since both of these latter students also reported reviewing five lectures on-line, it is reasonable to consider five lectures as the upper bound of the number of classes skipped due to the availability of recorded lectures.

These results are consistent with findings of other studies. For example, the 2009 ECAR Study of Undergraduate Students and Information Technology[3] published results indicating that nearly two-thirds of students polled either disagreed or strongly disagreed with the proposition that "I skip classes when materials from course lectures are available on-line." Another study[4] of the effect of unlimited access to on-line lectures showed no discernable effect on the attendance in two sections of an introductory psychology class. Likewise, a similar study[5] conducted in a second-year pharmaceutical therapeutics course showed no correlation between classroom attendance and the amount of time students accessed on-line lecture material.

Student comments

Students were asked to provide suggestions for improvements to the on-line lectures provided during this study. The most frequent suggestion was to add a video stream with a view of the blackboard so that the few examples worked out there could be seen, or so that the instructor's pointing to highlight projected information on the slides could be viewed. This capability is available with many lecture capture tools, including the Panopto tools. It was not used here due to the significant additional server storage required for the digitized video stream. The second most common problem that garnered comments was that students were unable to hear questions or comments from students in the classroom at the time of the lecture capture.

In summary, students found lecture captures to be very helpful and were generally very positive about the experience. Quite a few students made similar comments indicating that they wished that all their classes made this tool available.

Conclusion

Considering the ease of capturing and uploading lectures with integrated tools like Panopto Coursecast (now Panopto Focus), the benefits to students and their very positive impression of these on-line aids, and the lack of negative impact on classroom attendance, it is reasonable to expect that the very limited current deployment of this technology in engineering education programs should not continue. These resources will become far more ubiquitous in the next several years as tools improve, as server storage capacity continues to become more affordable, and as network bandwidths and infrastructure expand.

References

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Maximum Power Point Tracking (MPPT) Algorithm for Classroom Applications

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Abstract

The electric power industry will require an estimated 11,000 power engineers by the year 2014. As of today there are about 500 college degrees granted in power engineering. Therefore, it is anticipated that more power engineers will be in demand. Especially a power engineer specialized in solar energy will be more marketable in the utility industry.

As hands on opportunities on solar energy have increased at CSUN, MPPT has become a topic of interest

This paper presents the analysis and simulation of MPPT for teaching purposes. We will use Pspice simulation program and Matlab as tools to explain and deliver the material to the students. In order to measure the effectiveness of this approach, written and oral power point presentations will be conducted, as well as, one or two examinations.

Introduction

Solar energy has become one of the major "green," "renewable" energy sources in California. By the year 2020, Public and private electric utilities are mandated to generate 20% of their generation utilizing renewable energy. California State University Northridge and Boeing have deployed 100 KW solar tracking plant using dual axis tracking systems in our campus. This plant is being tested and our students are getting hands on experience in solar energy. Our curriculum is being adjusted to add solar energy analysis and models

Because efficiency of solar energy is becoming the most important issue, MPPT is necessary to improve the performance of solar tracking systems. There are several algorithms that claim to be better than the others; it is for this reason that we will focus in one algorithm only to explain the concept. We will start with the theoretical explanation of MPPT and continue with the simulation.

Photovoltaic power systems are usually integrated with some specific control algorithms to deliver the maximum possible power [1]. Maximum power point tracking (MPPT) is essential because it takes full advantage of the available solar energy. Two most widely adopted tracking methods in PV power systems are the pertubation and observation method (P&O) [2] and the incremental conductance method (IncCond) [3]. PV power systems using these tracking methods regulate the voltage of the PV array to follow an optimal setpoint (V_{OOP}, the voltage of optimal operating point, or V_{MPOP}, the voltage of maximum power operating point), satisfying the *dP/dV=0* condition at the local maximum power operating point. However, due to an intrinsic problem of oscillation around the optimal operating point and the difficulty in choosing the pertubation step of the PV voltage setpoint, according to [1], it is more desirable to determine the V_{OOP} directly during the real-time operation instead of tracking it simlply through trial and error.

A More general real-time identification method for MPPT is the utilization of polynomial curve fitting and the process of parameterization, which is proposed by [1], along with other modeling techniques.

Solar Cell Modeling

In this section several models of a solar cell are presented [1]: traditional single-diode equivalent circuit model [4], simplified single-diode model (SSDM) [5], further simplified single-diode model (FSSDM) [6], and polynomial curve fitting (PCF) model. An Equivalent circuit of the traditional single-diode model is shown in Fig. 1, including four components, namely: 1) a photocurrent source I_{ph}; 2) a diode D parallel to the source; 3) a series resistor R_s; and 4) a shunt resistor R_p. There are five unknown parameters in this model. The mathematical description of the I-V characteristics for this model is represented by a coupled nonlinear equation which is difficult to solve analytically in real-time operation. Hence, simpler models are introduced for the real-time application

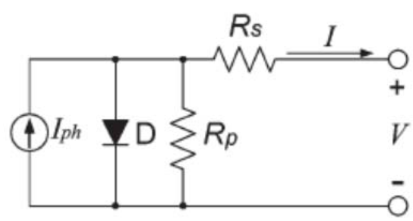

Fig. 1 Traditional Single Diode Model

Simplified single-diode model (SSDM) of solar cells

Fig. 2 is the equivalent circuit of a simplified single-diode model (SSDM) of PV cells. The current through a PV cell is given by;

$$i = i_{ph} - i_{sat}\left[e^{\left(\frac{v+iR_s}{v_t}\right)} - 1\right] \qquad (1)$$

$$v_t(T) = \frac{AkT}{q} \qquad (2)$$

Where i_{ph} represents the photocurrent, v is the voltage across the cell, v_t is the thermal voltage, R_s is the series resistor, and i_{sat} is the saturation current of the diode. The thermal voltage v_t is a function of temperature T, where A represents the ideality factor of the diode, k is the Boltzmann's constant, and q stands for the charge of an electron.

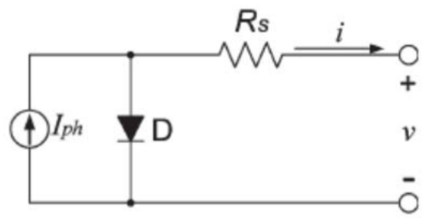

Fig. 2 Equivalent circuit of a SSDM

Further SSDM (FSSDM) of solar cells

Fig. 3 is the equivalent circuit of further simplified single-diode model (FSSDM) of solar cells.

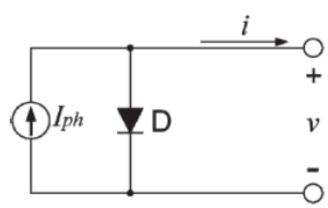

Fig. 3 Equivalent circuit of a FSSDM

Current-voltage relationship of this model can be expressed as;

$$i = i_{ph} - i_D = i_{ph} - i_{sat}\left[e^{\left(\frac{v}{v_t}\right)} - 1\right] \quad (3)$$

Polynomial curve fitting (PCF)

A polynomial curve fitting (PCF) method is proposed in this study to represent the electric characteristics of PV modules.

Parameterization of the equivalent circuits of PV cells (SSDM)

According to [1], under the short-circuit situation in the equivalent circuit, the photocurrent i_{ph} is approximated as;

$$\hat{i}_{ph} = \tilde{I}_{sc} \qquad (4)$$

Where $\hat{i}_{ph}$ is the estimated photocurrent i_{ph} and $\tilde{I}_{sc}$ is the measured short-circuit current at a certain test condition with constant irradiance and temperature. Based on the open-circuit condition in the equivalent circuit, the saturation current i_{sat} of the diode is expressed as

$$\hat{i}_{sat} = \frac{\hat{i}_{ph}}{e^{\left(\frac{\tilde{V}_{oc}}{v_t}\right)} - 1} \qquad (5)$$

The variable $\hat{i}_{sat}$ represents the estimated saturation current i_{sat}, and $\tilde{V}_{oc}$ is the measured open-circuit voltage at the same test condition as that of the short-circuit measurement. The MPP (v_{mpp}, i_{mpp}) is measured through experimental tests under the identical test environment. At the MPP of a SSDM,

$$i_{mpp} = i_{ph} - i_{sat}\left[e^{\left(\frac{v_{mpp}+i_{mpp}R_s}{v_t}\right)} - 1\right] \qquad (6)$$

Substitution of (4) and (15) into (6) gives;

$$i_{mpp} = \tilde{I}_{sc} - \left[\frac{e^{\left(\frac{v_{mpp}+i_{mpp}R_s}{v_t}\right)} - 1}{e^{\left(\frac{\tilde{V}_{oc}}{v_t}\right)} - 1}\right]\tilde{I}_{sc} \qquad (7)$$

Relationship of R_s and v_t in SSDM can be obtained by reorganizing (7).

$$R_s = \frac{v_t \ln\left[\left(1-\frac{i_{mpp}}{\tilde{I}_{sc}}\right)e^{\left(\frac{\tilde{V}_{oc}}{v_t}\right)} + \frac{i_{mpp}}{\tilde{I}_{sc}}\right] - v_{mpp}}{i_{mpp}} \quad (8)$$

The MPPs occur when *dP/dV=0,* where *P* is the PV module's output power and *V* is the PV voltage, and the equation can be represented by

$$\left.\frac{di}{dv}\right|_{v=v_{mpp}} + \frac{i_{mpp}}{v_{mpp}} = 0 \quad (9)$$

Differentiating (1) gives

$$\frac{di}{dv} = -i_{sat}\left\{e^{\left(\frac{v+iR_s}{v_t}\right)}\left[\frac{1}{v_t} + \left(\frac{R_s}{v_t}\right)\frac{di}{dv}\right]\right\} \quad (10)$$

This gives

$$\left.\frac{di}{dv}\right|_{v=v_{mpp}} = -\frac{\frac{\hat{i}_{sat}}{v_t} e^{\left(\frac{v_{mpp}+i_{mpp}R_s}{v_t}\right)}}{1+\frac{\hat{i}_{sat}R_s}{v_t} e^{\left(\frac{v_{mpp}+i_{mpp}R_s}{v_t}\right)}} \quad (11)$$

According to [1], the parameters in (1) or (3) that best represent the output characteristics of the solar cell can be numerically determined by solving (9) numerically. Bisection, the Newton-Raphson method (NRM), and Secant [8] are examples of available numerical analysis algorithms. For the MATLAB simulations for this study, the NRM is utilized.

Results of independent simulations

SSDM was simulated independently by using PSPICE. The following netlist was used for the simulations of SSDM of MSX-83 (a polycrystalline silicon PV panel from Solarex). Values of iscmr (short-circuit current), pmaxmr (maximum output power), and vocmr (open-circuit voltage) are all obtained from the manufacturer's product specification sheet.

```
* MSX83_SSDM.CIR
.include ssdm.lib
xmsx83_ssdm 0 43 42 ssdm params:ta=25,
+ tr=25, iscmr=5.27, pmaxmr=83,
+ vocmr=21.2, ns=36, np=1, nd=1
vbias 43 0 dc 0
virrad 42 0 dc 1000
.dc vbias 0 23 0.1
.probe
.end

*   SSDM.LIB
*
*   MODEL LEVEL 1
*
*   STANDARD AM1.5G
*   IRRADIANCE 1000 W/m2
*   SINGLE DIODE (DIFFUSION, D1)
*   CURRENT SOURCE
*   SERIES RESISTANCE RS IS INTERNALLY CALCULATED
*   BUILT-IN SPICE DIODE MODEL D
*   INPUT PARAMETERS:
*   TA, AMBIENT TEMPERATURE
*    TR, CELL TEMPERATURE
*   ISCMR, SHORT-CIRCUIT CURRENT
*   PMAXMR, MAXIMUM OUTPUT POWER
*   VOCMR, OPEN-CIRCUIT VOLTAGE
*   NS, NUMBER OF CELLS IN SERIES
*   NP, NUMBER OF CELLS IN PARALLEL
*   ND, DIODE IDEALITY FACTOR
*   SUBSCRIPT R INDICATES REFERENCE
*   CONDITIONS
*   NODES
*   (400) REFERENCE
*   (401) INTERNAL NODE
*   (402) INPUT, IRRADIANCE
*   (403) OUTPUT
.subckt ssdm 400 403 402 params: ta=1, tr=1, iscmr=1,
+ pmaxmr=1, vocmr=1, ns=1, np=1, nd=1
```

```
girradm 400 401 value={(iscmr/1000*v(402))}
d1 401 400 diode
.model diode d(is={iscmr/(np*exp(vocmr/(nd*ns*
+ (8.66e-5*(tr+273)))))},n={nd*ns})
.func uvet() {8.66e-5*(tr+273)}
.func vocnorm() {vocmr/(nd*ns*uvet)}
.func rsm() {vocmr/(iscmr)- pmaxmr*(1+vocnorm)/(iscmr**2*(vocnorm-
+ log((vocnorm)+0.72)))}
rs 401 403 {rsm()}
.ends ssdm
```

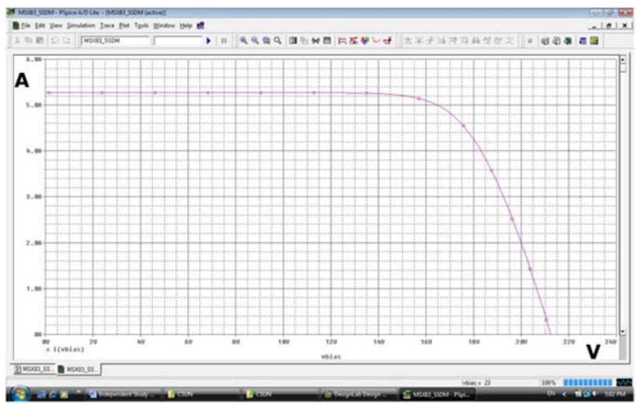

Fig. 4 PSPICE simulation of SSDM of MSX-83

The following netlist was used for the simulation of SSDM of ST-10 (a copper-indium-diselenide, or CID, thin film PV panel from Shell Solar). Values of i_{scmr}, p_{maxmr}, and v_{ocmr}, again, are all obtained from the manufacturer's product specification sheet.

```
* ST10_SSDM.CIR
.include ssdm.lib
xst10_ssdm 0 43 42 ssdm params:ta=25,tr=25,
+ iscmr=0.77, pmaxmr=10, vocmr=22.9,
+ ns=42, np=1, nd=1
vbias 43 0 dc 0
virrad 42 0 dc 1000
.dc vbias 0 23 0.1
.probe
.end
```

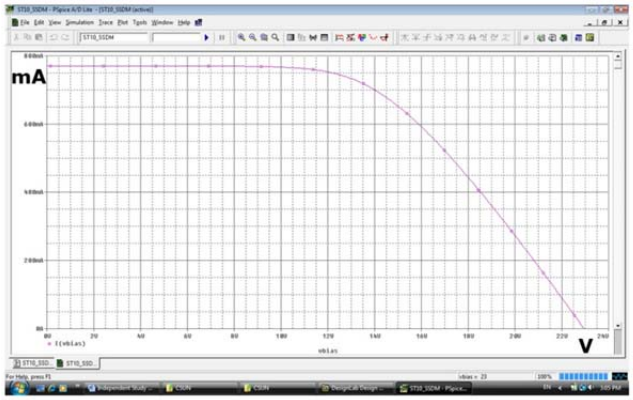

Fig. 5 PSPICE simulation of SSDM of ST-10

The following netlist was used for the simulations of FSSDM of MSX-83.

```
* MSX83_FSSDM.CIR
.include fssdm.lib
xmsx83_fssdm 0 41 42 fssdm params:ta=25,tr=25,
+ iscmr=5.27, pmaxmr=83, vocmr=21.2,
+ ns=36, np=1, nd=1
vbias 41 0 dc 0
virrad 42 0 dc 1000
.dc vbias 0 23 0.1
.probe
.end

*    MSX83_FSSDM.LIB
*
*    MODEL LEVEL 1
*
*    STANDARD AM1.5G
*    IRRADIANCE 1000 W/m2
*    SINGLE DIODE (DIFFUSION,D1)
*    CURRENT SOURCE
*    SERIES RESISTANCE RS IS IGNORED
*    BUILT-IN SPICE DIODE MODEL D
*    INPUT PARAMETERS:
*    TA, AMBIENT TEMPERATURE
*    TR, CELL TEMPERATURE
*    ISCMR, SHORT-CIRCUIT CURRENT
*    PMAXMR, MAXIMUM OUTPUT POWER
*    VOCMR, OPEN-CIRCUIT VOLTAGE
*    NS, NUMBER OF CELLS IN SERIES
*    NP, NUMBER OF CELLS IN PARALLEL
```

```
*    SUBSCRIPT R INDICATES REFERENCE
*    CONDITIONS
*    NODES
*    (400)REFERENCE
*    (401)OUTPUT
*    (402)INPUT, IRRADIANCE

.subckt fssdm 400 401 402 params: ta=1, tr=1, iscmr=1,
+ pmaxmr=1, vocmr=1,
+ ns=1, np=1, nd=1
girradm 400 401 value={(iscmr/1000*v(402))}
d1 401 400 diode
.model diode d(is={iscmr/(np*exp(vocmr/(nd*ns*(8.63e-+ 5*(tr+273)))))},n={nd*ns})
.func uvet() {8.66e-5*(tr+273)}
.func vocnorm() {vocmr/(nd*ns*uvet)}
.ends fssdm
```

The following netlist was used for the simulations of FSSDM of ST-10.

```
* ST10_FSSDM.CIR
.include fssdm.lib
xst10_fssdm 0 41 42 fssdm params:ta=25,tr=25,
+ iscmr=0.77, pmaxmr=10, vocmr=22.9,
+ ns=42, np=1, nd=1
vbias 41 0 dc 0
virrad 42 0 dc 1000
.dc vbias 0 23 0.1
.probe
.end
```

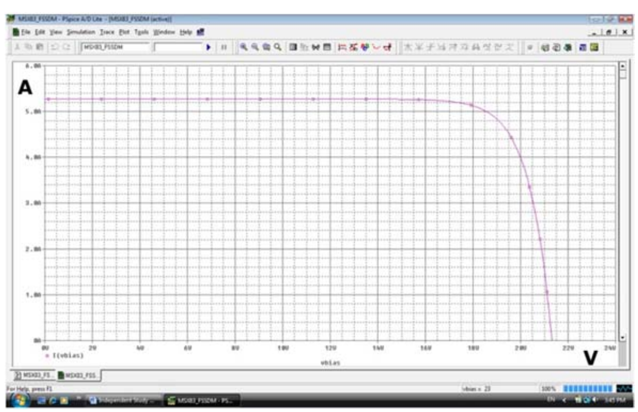

Fig. 6 PSPICE simulation of FSSDM of MSX-83

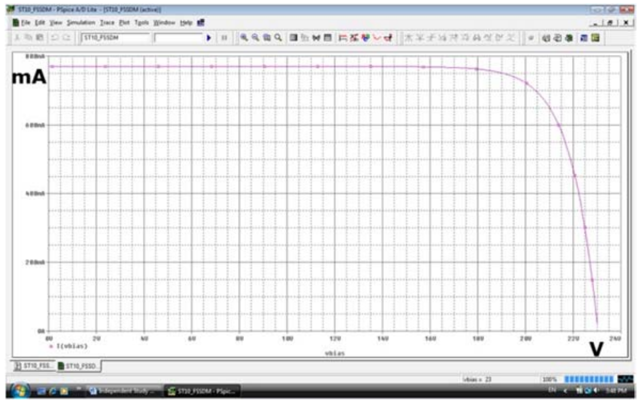

Fig. 7 PSPICE simulation of FSSDM of ST-10

Time estimation of the mpp

In this section the principle and procedure of real-time estimation of MPP are presented in detail. Due to the variation of "*insolation*" and cell temperature, system parameters change continuously. Recursive least squares estimation (RLS) and NRMs are two major featured algorithms to determine the system parameters. By using RLS [7], the parameters of the polynomial models are obtained and updated recursively by minimizing the error between prediction and measurement. NRM method [8] is another recursive algorithm used to determine the voltage of the optimal operating point (V_{OOP}). Fig. 8 is the flowchart of RLS operation. Fig. 8 is the flowchart of the NRM operation.

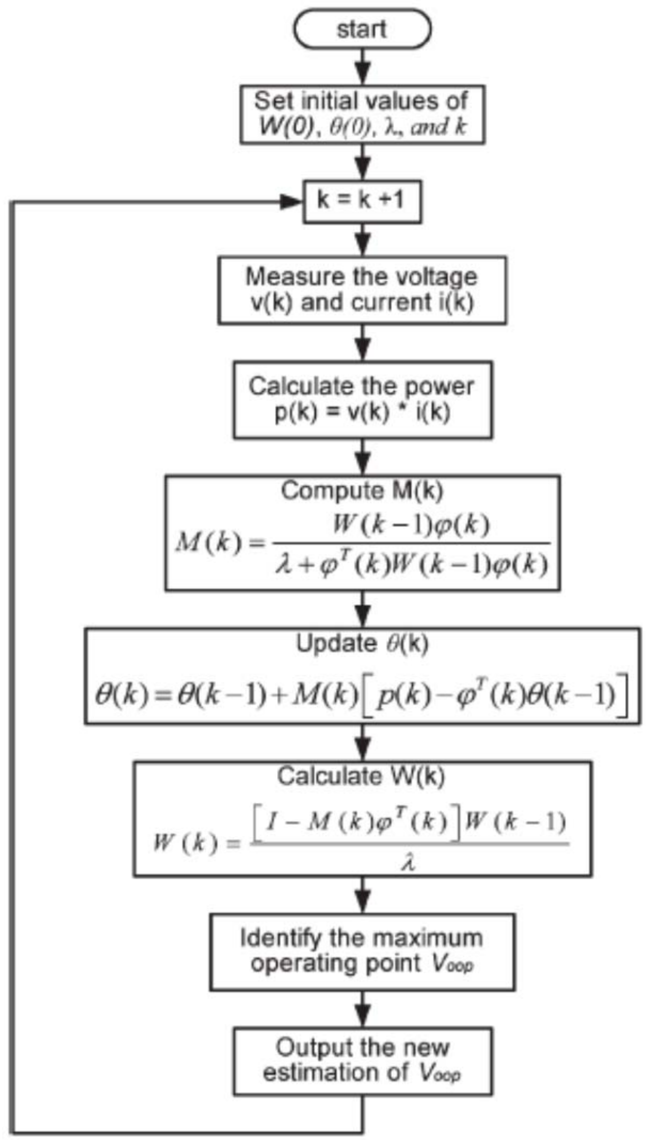

Fig. 8 Flowchart of the RLS estimation procedure to determine the system parameters

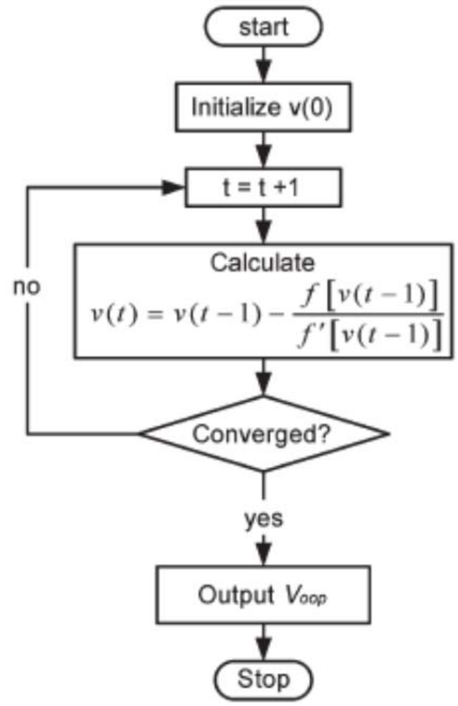

Fig. 9 Flowchart of the NRM operation in finding V_{OOP}

Interested readers are highly recommended to refer to [7] and [8], as well as [1], to find out further about RLS and NRM, as well as the applications of that algorithm in MPPT.

Assessment

Theoretical explanations of solar cells will be provided during the introductory lecture week (3/1/2 hours), whereas the simulation will be conducted by the students during the following week of the same semester. Students will already have a working knowledge of Pspice. The pre-test will be implemented at the end of the theoretical explanations of a solar cell. The post-test will be implemented at the end of the week of simulations. For pre and post tests quiz format will be used with the same questions.

The comparison of pre and post tests will indicate the impact of simulations on learning outcomes. It will also identify what needs to be changed to improve the delivery of the material. This process will be carried on this semester in week 10 and 11 of the power electronics and photo-voltaic (PV) course.

Conclusions

In [1], the major modeling features of the photovoltaic modules (equivalent circuit models and PCF) are presented. As for the this project, I-V characteristic curves of Solarex MSC-83 and ST10 of Shell Solar's photovoltaic modules were simulated successfully by using PSPICE. A comparison of the maximum power specified by the manufacturer and the one obtained by simulation yielded no significant error. This simulation exercise is expected to add to student learning

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Cost-Effective Integration of Tablet Technology into Engineering Courses

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Abstract

Current generations of students are part of a digital revolution in which they collaborate and learn through digital mediums and remain connected 24/7. Educators across the board have embraced these rapid changes and, with the aid of classroom technologies such as Tablet-PCs (TPC), have seamlessly transformed traditional teacher-dominated classrooms into dynamic, digitally rich student-centered learning environments. In order to bestow a competitive advantage on their students, nations are investing heavily in digitally rich environments to boost student learning and achievement of their future workforce, which in turn will help them remain competitive in the global marketplace. Therefore, widespread and fast adoption of digital learning technologies such as TPC are imperative for increasing probability of student success, thus maintaining our nation's competitiveness. However, educators face daunting challenges at different levels to create a digitally rich environment using tablet technology thus prohibiting its widespread adoption. This paper discusses a cost-effective integration of Tablet technology into traditional engineering courses to make students' classroom experience more efficacious. The paper includes resources needed to convert existing classrooms into either a "single-tablet model" or a "multi-tablet model" and also evaluates the hypothesis that integration of tablet technology, using cost-effective USB-Tablets increases, student learning by means of student evaluation.

I. Introduction

It is a well-accepted fact that with the digital revolution, the structure and nature of student learning has changed dramatically from what was and continues to evolve. Current generations of students are part of this digital revolution where they collaborate and learn through digital mediums and remain connected 24/7. Educators across the board have embraced these rapid changes and, as a result, today's classrooms have been restructured resulting in shifts in teaching from a traditional teacher-dominated approach to a dynamic, digitally rich student-centered approach that enables students to be self-learners.

One of the technologies that facilitated this shift is the Tablet-PCs (TPC). TPC in combination with an interactive educational software (such as *Dyknow Vision* and *Classroom Presenter*) and classroom management software (such as *Dyknow Monitor* and *LanSchool*) have helped to seamlessly transform traditional classrooms into digital learning environments. Using this technology, instructors can, a) progressively present both prepared and extemporaneous class material using digital ink which can be saved for future review, b) solicit active participation from all students during lectures to conduct immediate and meaningful assessments and to provide needed feedback and assistance in realtime to maximize student learning, c) be mobile, d) face the class and not obstruct visual presentation of material, e) remotely monitor each student during class sessions and minimize "electronic distraction." TPC improves student learning and allows students to view information on their computer, take personal notes directly on provided slides, and save the information for future reference and review. The numerous implementations of TPC demonstrate the usefulness of this technology to increase interaction between faculty and students and it has shown improvement in learning and retention of material [1 – 4]. TPC is suited for analyzing and solving engineering problems and it provides an ideal venue for applying interactive teaching.

In order to bestow a competitive advantage on their students, nations are investing heavily in digitally rich environments to boost student learning and achievement of their future workforce, which in turn will help them remain competitive in the global marketplace. Therefore, widespread and fast adoption of digital learning technologies such as TPC, that have proven to enhance student learning, are imperative for increasing probability of student success, thus maintaining our nation's competitiveness. However, educators face daunting challenges at different levels to create a digitally rich environment using tablet technology thus prohibiting its widespread adoption. The primary impediment is the prohibitive hardware cost of digital learning technologies like TPC.

This paper discusses a cost-effective integration of Tablet technology into traditional engineering courses to make students' classroom experience more efficacious. The integration will rely on USB-Tablets ($58 - $170) along with interactive educational and classroom management software. The paper includes resources needed to convert an existing classroom with PCs into either a "single-tablet model" or a "multi-tablet model." The paper also evaluates the hypothesis that integration of tablet technology using cost-effective USB-Tablets increases student learning by means of student evaluation.

II. USB-Tablets

Fig. 1. Wacom Wired USB-Tablet with 5.8" x 3.6" active area ($58)

Fig. 2. Wacom Wired USB-Tablet with 8.5" x 5.4" active area ($170)

A USB-tablet is a computer input device connected to the USB port of the computer that allows one to write and hand-draw images using a stylus, a pen-like drawing apparatus. The image does not appear on the tablet itself but, rather, is displayed on the computer monitor. There are a variety of USB-tablets available in the market today ranging in size (active area), and capabilities (Figs.1 and 2). Wireless tablets (Fig.3) are also available that will enable the instructor to be mobile.

Fig. 3. Wacom wireless pen tablet with 8.0" x 5.0" active area ($374)

III. Single-Tablet and Multi-Tablet Models using USB-Tablets

In the single-tablet model, the instructor's tablet is connected to the PC with a projection system. Single-tablet models can be used in classrooms along with interactive educational software or with freeware such as *ScreenPen* alone that allows you to highlight, write and save slides with annotations using digital ink for future reference. Wireless tablets (Fig.3) are an ideal choice for the single-tablet model classrooms. Using this model, any traditional classroom can be seamlessly converted to a digital learning environment in a cost-effective manner as only a single tablet is required. However, the single-tablet model lacks the ability to gather instant student feedback using digital ink.

In the multi-tablet model, both the instructor and students have USB-Tablets. This model can be adopted in classrooms with networked PCs installed with interactive educational and classroom management software. The single-tablet and multi-tablet models using USB-tablets are not only as effective as the TPCs but are also a cost-efficient method to integrate tablet technology into classrooms.

IV. Pilot Study - Single-Tablet Model Implementation in Two New Engineering Courses

In Fall 2010, a pilot study using USB-Tablet was conducted to ascertain its effectiveness in engineering courses. The single-tablet model using USB-Tablet (Fig. 2) was adopted in two new engineering courses, 1) EGGN100 – *Introduction to Engineering* (Total enrollment: 84, two sections) and 2) EGCP 456 – *Introduction to Logic Design in Nanotechnology* (Total enrollment: 13, one section). *ScreenPen* freeware was utilized to elaborate concepts using digital ink annotations (Fig. 4).

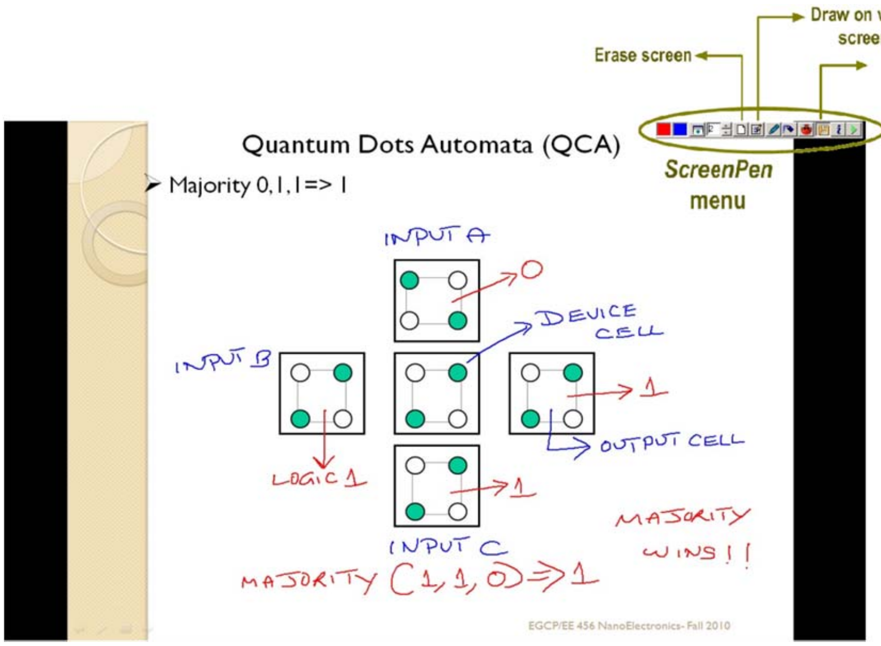

Fig. 4. Annotations using digital ink on lecture slides in EGCP 456 class

a) Challenges Encountered

One of the challenges faced was the selection of appropriate software for digital ink annotations. During the first few weeks of class, several freeware programs were tried out. While some software crashed during lectures, several others slowed down the presentation delivery as they were CPU intensive. *ScreenPen* freeware however proved to be a good resource that came with a simple menu along with a user friendly interface.

The second challenge encountered was the hand-eye coordination that is required as images drawn on the tablet do not appear on the tablet itself unlike a TPC but, rather, are displayed on the computer monitor. This is very similar to the hand-eye coordination required for a computer mouse. However, just as with the computer mouse, good hand-eye coordination was gained with USB-Tablets with minimal practice.

b) Student Feedback and Analysis

A student survey was constructed to measure students' perceptions of the USB-Tablets in engineering classrooms. The survey included four questions with responses: strongly disagree, disagree, neutral, agree, strongly agree along with two questions with free-response answers. The overall student response was lower than expected (EGGN 100 (section 1): 17/31, EGGN 100 (section 1): 37/53, EGCP 456: 9/13).

Fig. 5(a) summarizes the student response to the first question in survey, "*Using the Tablet technology increased my understanding of the lecture.*" Approximately 52% of the students

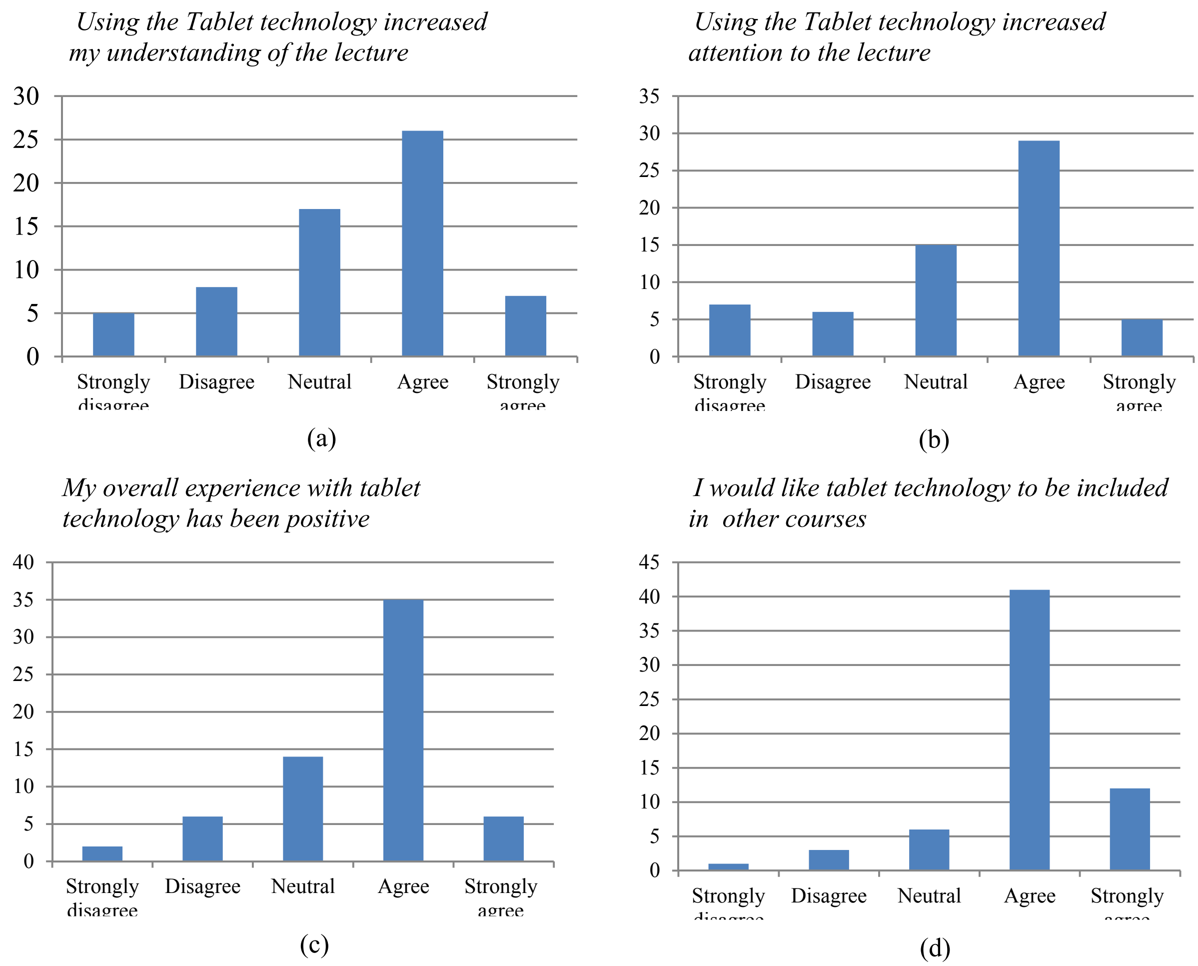

Fig. 5: Student survey questions and feedback

agree that their understanding of the lecture was improved with the use of tablet technology in their class. Many students pointed out in their free-response answers that with the tablet technology they were able to focus on comprehending the class material rather than taking notes for future reference. Fig. 5(b) summarizes the student response to the second question in survey, "*Using the Tablet technology increased attention to the lecture.*" Approximately 55% of the students agree that they were more attentive during the lecture as the use of tablet technology helped them focus on a single location rather than taking notes from different parts of a white board. The overall survey response from students and their personal feedback on the effectiveness of the USB-Tablet in improving their learning experience was positive. Approximately 65% of the students surveyed agree that they had a positive experience with the use of tablet technology in the class (Fig. 5(c)) and 84% of the students wanted tablet technology to be included in other classes as well (Fig. 5(d)).

The sample size involved in this pilot study was small. Classes of larger sizes are needed in the future to further study its effectiveness and also to verify the benefits of instruction in larger class sizes. Furthermore, the impact and effectiveness of USB tablets in class needs to be evaluated using a control group that uses traditional teaching techniques, and an experimental group that uses the tablet technology.

V. Conclusion

A cost-effective integration of tablet technology into traditional engineering courses to make students' classroom experience more efficacious was described. The paper included resources needed to convert an existing classroom with PCs into either a "single-tablet model" or a "multi-tablet model." The survey used to measure students' perceptions of the USB-Tablet implementation in two new engineering courses was analyzed. The overall survey response from students and their personal feedback on the effectiveness of the USB-Tablet in improving their learning was positive. However, to further study its effectiveness and to verify the benefits of instruction more case studies with larger sizes are needed. Furthermore, the impact and effectiveness of USB tablets in classrooms needs to be evaluated using a control group that uses the traditional teaching techniques and an experimental group that uses tablet technology.

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A Method for Adjusting Group-Based Grades

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Abstract

Instructors have long sought a method of assigning credit for group work equitably. The Department of Mechanical Engineering at the University of Nevada, Reno offers two first-year engineering courses and each contains large group work components. For assessment purposes, the instructors felt that the individual course grades needed to be adjusted to accommodate for the portion of the grade that is defined by group work in these courses. Individual grades are a reflection of a student's actual work, whereas the group grade is easily confounded by the effects of their team mates (positively and negatively).

Assigning grades to individuals for a group project is important because instructors want to assign grades based on effort. Since all students in a group typically receive the same grade for a group assignment (e.g. a group report), group grades have the undesirable effect of obscuring a student's true performance, especially if group work constitutes a large portion of the final grade. Thus, it is desirable to develop a method which could be used to more accurately reflect the true contribution of each student within a group.

The instructors tried using several methods to determine the distribution of effort within the teams including merit pay (a form of extra credit based on peer evaluations), team journals (where teams self report the distribution of effort), and computerized team evaluations (e.g. CATME, which won the 2009 Engineering Pathways Premier Software award). All of these methods can be used by the instructor to redistribute the group grade based on individual effort. In this research, an automated method of adjusting the group grade is proposed and tested.

The new method was developed to adjust grades within each group based on the residual of the individual grades within the group and the portion of the course grade defined by group work. It was found that the grade adjustment method agreed 78% of the time with the manual grade changes instructors made in 2009, and also increased the correlation between group grades and individual grades.

It is recommended that the adjustment method only be used for assessment purposes and not for the actual computation of a student's grade for several reasons. First, the method is difficult to explain to students. Secondly, students would not be able to calculate their grade without knowing the grades of their teammates (a violation of privacy laws). Lastly, students already dislike having their grade dependent on the performance of their teammates and the proposed grading scheme would lead to a competitive rather than collaborative team environment.

Introduction

A method of assigning credit for group work that accurately represents individual effort within a group has been long sought out by instructors. The Department of Mechanical Engineering at the University of Nevada, Reno offers two first-year engineering courses and each contains large group work components. Individual grades are a reflection of a student's actual understanding of the course material, whereas the group grade is easily confounded (positively and negatively) by the effects of the work done by their team mates. In order to gain a true perspective of student performance for assessment purposes, the instructors of these courses felt that the individual course grades needed to be adjusted to accommodate for the portion of the grade that is defined by group work.

Assigning grades to individuals for a group project is important because instructors want to assign grades based on effort. When group work (e.g. a group report) constitutes a large portion of the final grade, the group grade can easily obscure the final grade, which makes the final grade an inaccurate measure of individual student performance. Thus, developing a method which could be used to more accurately reflect the true contribution of each student within a group is desirable.

The instructors tried using several methods to determine the distribution of effort within the teams including merit pay (a form of extra credit based on peer evaluations), team journals (where teams self report the distribution of effort), and computerized team evaluations (e.g. CATME, which won the 2009 Engineering Pathways Premier Software award). These methods are time consuming; however, all of these methods can be used by the instructor to redistribute the group grade based on individual effort. In this research, an automated method of adjusting the group grade is proposed and tested.

Methods

Sampling

The grade adjustment method presented in this paper was evaluated using two introductory engineering classes (ENGR 100 and ME 151) at the University of Nevada, Reno. The College of Engineering at the University of Nevada, Reno is comprised of five departments, four of which participate in ENGR 100: Mechanical Engineering (ME), Civil Engineering (CE), Electrical and Biomedical Engineering (EBME) and Chemical and Metallurgical Engineering (CME). ENGR 100 is a required multi-disciplinary first-year engineering course that was developed with funding from the William and Flora Hewlett Foundation[1]. This course is taught once per year (fall semester) and traditionally has a combined enrollment of approximately 300 students.

Students attend a large 1-hour lecture twice a week and then break up into small sections of 24 students for a 1.5 hour weekly lab. The overall goal of ENGR 100 is to teach students about the various aspects of the engineering design process via completion of a semester long design project. The project consists of students working in groups of 5-9 to design and build either a vibration monitor (2005-2007) or a hovercraft (2008-present).

The Mechanical Engineering (ME) and Material Science Engineering (MSE) Departments at the University of Nevada, Reno are also participating in a multi-disciplinary first-year project funded by the William and Flora Hewlett Foundation[1]. As part of this project, an interdisciplinary freshmen-level course (ME151/MSE102) is taken by all mechanical engineering and material science engineering undergraduates. Traditionally, these two courses have a combined enrollment of approximately 125 students.

As stated in the course syllabus, the overall goal of the course is for the student to learn the fundamentals of structured computer programming, the design process, and creative thinking. In order to accomplish this goal, students work in pairs to create autonomous robots with LEGO bricks and a computer program called ROBOLAB.

Procedure

It is reasonable to assume that a team consisting of members, whom all received C's on their individual assignments would earn a low grade on their group work when compared to a team consisting entirely of A students (as measured by their individual grades). This assumption is based on the fact that the group work in most classes requires that the students display a mastery of the skills learned from the assignments completed as an individual.

The premise put forth is that as the range of individual grades within a team increased, the group grade would be less correlated with the individual grades. Figure 1, Figure 2, and Figure 3 show the relationship between individual and group grades categorized by the range among individual grades within a group being less than 25; between 25 and 50; and greater than 50 respectively for ENGR 100 in 2005.

Based on this, a method was sought to adjust grades to reflect individual ability that would not impact a team consisting of similarly performing students (e.g. Figure 1) but would adjust the grades of students on a team that displayed a large variation in individual performance (e.g. Figure 3).

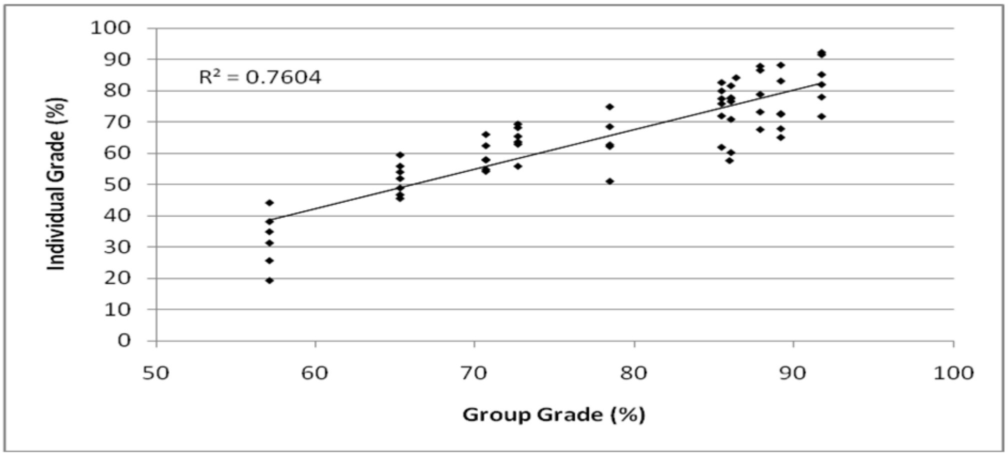

Figure 1: The relationship between individual and group grades categorized by the range among individual grades within a group being less than 25 for ENGR 100 in 2005.

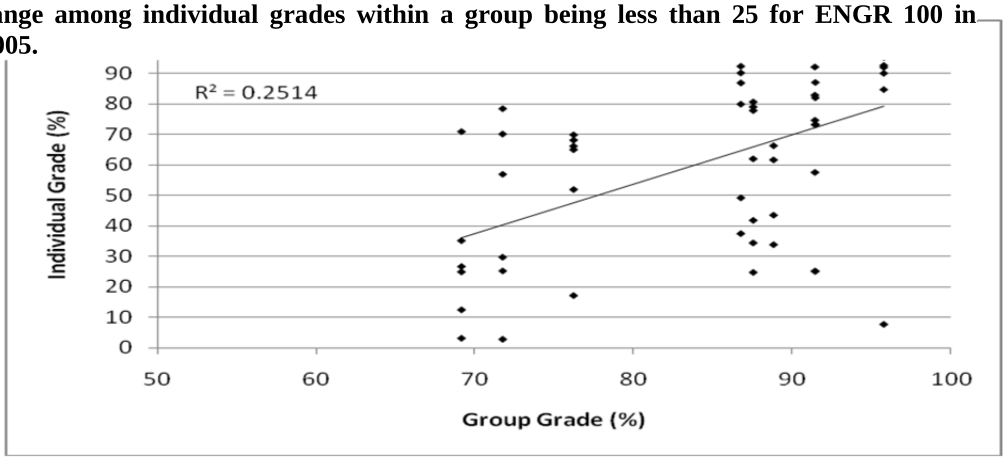

Figure 3: The relationship between individual and group grades categorized by the range among individual grades within a group being greater than 50 for ENGR 100 in 2005.

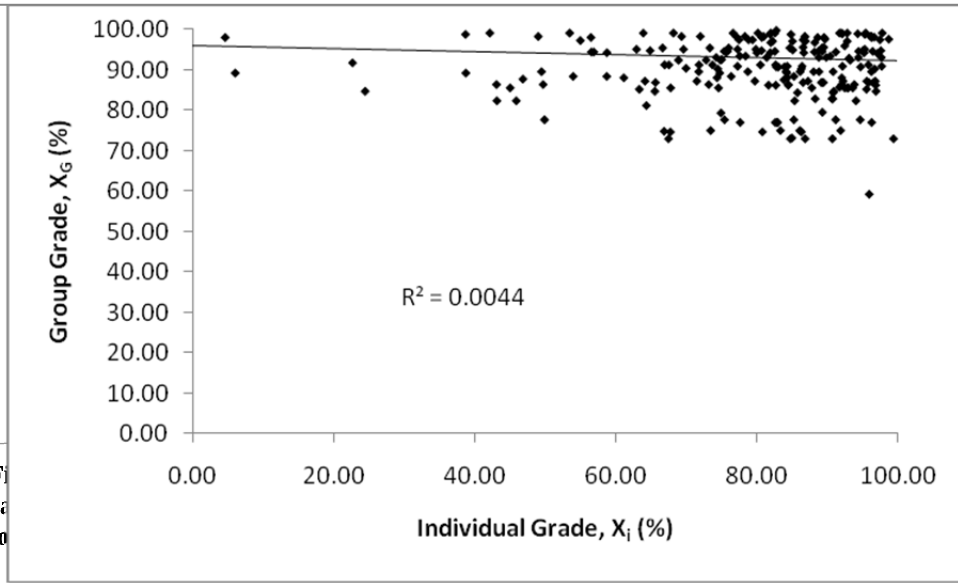

Figure 4: The relationship between individual grades and group grades for ENGR 100 in 2009. The correlation between individual and group grades is 0.004 indicating that the two grades are unrelated.

Traditionally a student's grade, G, is defined by the sum of their group (X_G) and individual score (X_i) as shown in Eq. 1

$$G = X_G + X_i \tag{1}$$

Figure 4 shows the relationship between individual grades (X_i) and group grades (X_G) for ENGR 100 in 2009. The correlation coefficient between individual and group grades is 0.004 indicating that the two grades are essentially unrelated even though one would expect some correlation for the reasons discussed above. Notice in Figure 4 that the leftmost students have comparatively low individual grades, yet they have high group grades.

In order to adjust the traditional group grade to the adjusted group grade, G*, the following steps were implemented:

1. Calculate the mean, $\overline{X}_i$, for individual grades within each group.

2. Convert individual scores into residual scores within their respective groups($X_i - \overline{X}_i$).

3. Multiply each individual's residual score by a constant, *m*, which is equal to the weight of the group grade as a percentage of the total grade (i.e. *m*=0.10 would reflect 10 of the total grade is based on the group grade). Add this number to the individuals group score to obtain an adjusted group score (Eq. 2).

$$X_G^* = m(X_i - \overline{X}_i) + X_G \tag{2}$$

4. Next add the adjusted group score to their individual score as shown in Eq. 3.

$$G^* = X_G^* + X_i \tag{3}$$

Eq. 4 summarizes steps 1-4, which adjusts an individual's final grade to reflect both the individual grade and the group grade.

$$G^* = m(X_i - \bar{X}_i) + X_G + X_i \tag{4}$$

The residual score ranks the group members scores from negative to positive according to their performance in comparison to their group (Eq. 2), so it adjusts their group score in both directions as well. Since the work associated with individual grades provide students with the skills they need to contribute to the project that determines their group grade, it was believed the group grade is not a fair representation of the work that each individual contributed to the project. Thus group grades were adjusted using the steps listed above. Figure 5 shows the relationship between individual grades and adjusted group grades. The correlation between individual and adjusted group grades increased to 0.264.

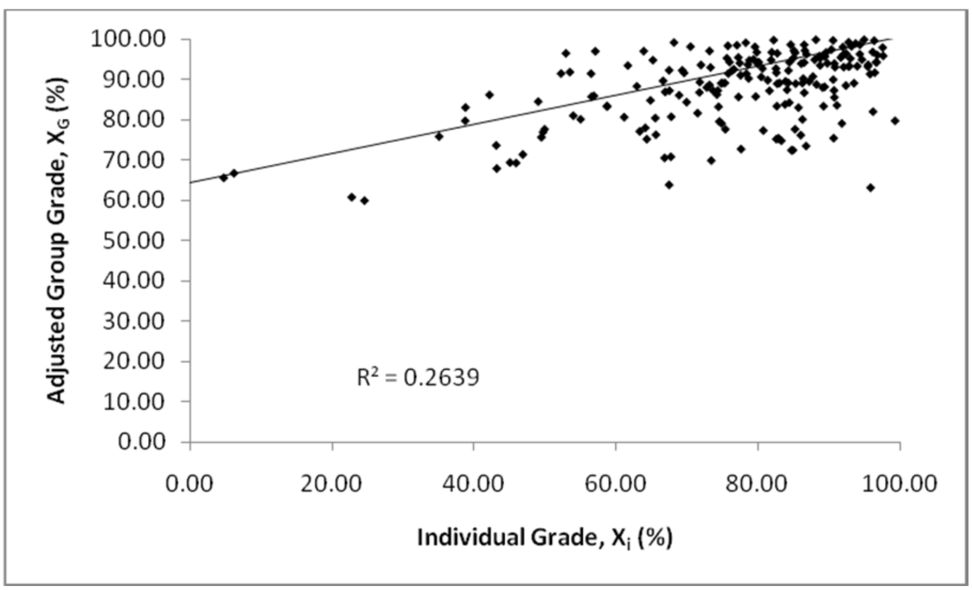

Figure 5: The relationship between individual grades and group grades for ENGR 100 in 2009. The correlation between individual and adjusted group grades increased to 0.264.

Results and Discussion

Table 1 and Table 2 list the correlation coefficients between individual grades and original and adjusted group grades when m=0.5 (in both ENGR 100 and ME 151, 50% of the grade is based on team work). Individual and adjusted group grades have a much higher correlation coefficient in all cases, which is expected since the adjusted group grade is dependent on the individual grade.

The grade adjustment method provides a more realistic range of data, since group grades are adjusted based on individual performance. It also improves the correlation between individual grades and group grades and seems to provide a more accurate course grade. Additionally this method provides a means to automate the grade adjustment method that instructors currently attempt to accomplish manually.

Table 1: The correlation coefficients between individual and group grades for ENGR 100 grades when m=0.5. The correlation coefficient is much greater when data is treated with Eq. 4.

Year	Original	Adjusted	Team Size
2005	0.358	0.861	6
2006	0.262	0.738	6
2007	0.262	0.737	6
2008	0.108	0.721	9
2009	0.004	0.264	6

Table 2: The correlation coefficients between individual and group grades for ME 151 grades when m=0.5. The correlation coefficient is much greater when data is treated with Eq. 4

Year	Original	Adjusted	Team Size
2005	0.132	0.961	2
2006	0.000	0.972	2
2007	0.126	0.960	2
2008	0.062	0.960	2
2009	0.030	0.965	2

Anecdotally, the proposed method of adjusting the group grades correlates with what instructors are attempting to accomplish manually. In 2009, for example, the instructors adjusted group grades based on review of team journals, which included self-reported effort distribution forms that all team members are required to sign. Based on these forms, the instructors adjusted the final grades of about 10% of the teams. In 78% of the cases, the automated method described above altered the individual's grade in the same direction (upwards or downwards) as the instructors' manual method. This correlation is surprisingly good in light of the fact that student are notorious for not reporting effort truthfully on self-reported forms.

Despite these preliminary results, validation of the grade adjustment will necessitate much more work. An extensive amount of data would need to be collected to corroborate the results of the grade adjustment technique. Interviewing each member of a group would provide a much more accurate view of how the group is performing and who is responsible for the work being completed. Journals would need to be reviewed for indicators of work distribution as well. Comprehensive Assessment for Team-Member Effectiveness (CATME) allows students to anonymously evaluate themselves as well as their teammates for performance within their group and contribution to work load[2]. CATME results could be collected and reviewed to try to prove that the grade adjustment method is effective as well.

Conclusion

This paper outlines a new method developed to adjust grades within a group based on the residual of the individual grades within the group and the portion of the course grade defined by group work. It was found that the grade adjustment method agreed 78% of the time with the manual grade changes instructors made in 2009, and also increased the correlation between group grades and individual grades.

The grade adjustment method has strong potential as a prequel to evaluating course changes. It is recommended that the adjustment method be used for assessment purposes and not for the actual computation of a student's grade for several reasons. First, the method is difficult to explain to students. Secondly, students would not be able to calculate their grade without knowing the grades of their teammates (a violation of privacy laws). Lastly, students already dislike having their grade dependent on the performance of their teammates and the proposed grading scheme would lead to a competitive rather than collaborative team environment. Although distributing adjusted grades to students may be troublesome, using this grade adjustment method could be ideal when using grades to assess courses since it provides a view of student performance that is not confounded by group grades.

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Biographical Information

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