

2012 ASEE North Midwest Section Conference on ACTIVE LEARNING IN ENGINEERING EDUCATION



8:00 - 8:45 am	Registration and Continental Breakfast	Cascade
8:45 - 10:00 am	Welcome	Cascade
8:45 - 8:55 am	Program Chair: Steven Covey	
8:55 - 9:00 am	Daniel Gregory, Associate Provost of Research and Dean of Graduate Education	
9:00 - 10:00 am	Keynote Speaker: Eric Rotvold, Distinguished Technologist, Emerson Process Management	
10:00 - 10:15 am	Refreshment Break	
10:15 - 11:45 am	Session 1 - Moderator: Serdar Sezen	Voyageur
10:15 - 10:30 am	<i>Project-Based & Active Learning in Computer Engineering Education</i> W. Shi, A. Turkmen, C. Liu, R. Nelson, J. Bumblis, D. Olson; UW - Stout	
10:30 - 10:45 am	<i>Active Learning Strategies in a Project Management Course</i> B. Garry; South Dakota State University	
10:45 - 11:00 am	<i>A Pilot Study: Motivating Student to Engage in Programming Using Game-Like Instruction</i> R. Thamvichai, S. Supanakorn-Davila; St. Cloud State University, University of Wyoming	
11:00 - 11:15 am	<i>Design and Manufacture of Polymer Components for an Ink Pen: an Example of Project Based Curriculum in Engineering Technology at UW-Stout</i> J. Schultz, W. Stary, S. Springer, L. Stradins; UW - Stout	
11:15 - 11:30 am	<i>Development of Low-Cost, Hands-On Lab Experiments for an Online Mechanics of Materials Course</i> J. Douglas, M. Holdhusen; UW - Fox Valley, UW - Marathon County	
11:30 - 11:45 am	<i>Comparison of On-Campus and Distance Learning Preference in a Junior-Level Materials Science Course</i> M. Cavalli, J. Neubert, D. Worley; University of North Dakota	
11:45 am - 12 Noon	Break	
12:00 - 1:45 pm	Lunch	Cascade
	2011 Edward F. Mikol Award Presentation	
	Panel Discussion: Active Learning in Engineering Education	
	Panelists:	
	Troy Pierson, Remmele Engineering; Brandon Smith, Xcel Energy; Andrew Bekkala, SCSU; Mark Petzold, SCSU	
1:45 - 3:15 pm	Session 2 - Moderator: Ken Miller	Voyageur
1:45 - 2:00 pm	<i>Effectiveness of Self-Paced Graphics/Visualization Tutorial for Engineering Students (work-in-progress)</i> F. Masoom, A. Masoom; UW - Platteville	
2:00 - 2:15 pm	<i>Inspiring Students to Use Classroom Simulation Software to Model Industry Manufacturing Process</i> A. Arnold, L. Daul, B. Krull, R. Nebel, A. Pandian; UW - Stout	
2:15 - 2:30 pm	<i>The Role of Computer Aided Engineering Software in Undergraduate Education</i> J. Iselin; UW - Platteville	
2:30 - 2:45 pm	<i>The Computer-Aided Microwave Design System (CAMDS): Implementation and Verification</i> S.S. Sharma, D. Bais, D.A. Rogers; North Dakota State University	
2:45 - 3:00 pm	<i>The Impact of Real World Engineering Problems on Student Motivation in Calculus</i> J. Neubert, D. Worley, N. Kaabouch, M. Khavanin; University of North Dakota	
3:00 - 3:15 pm	<i>The Impact of Study Abroad on Students and Hosting Companies</i> R. Meisner; UW - Stout	
3:15 - 3:30 pm	Refreshment Break	
3:30 - 5:00 pm	Session 3 - Moderator: Tim Vogt	Voyageur
3:30 - 3:45 pm	<i>Technical and Pedagogical Issues with Embedded System Engineering Education</i> A. Turkmen, C. Liu, W. Shi, R. Nelson, J. Bumblis, D. Olson; UW - Stout	
3:45 - 4:00 pm	<i>Summer Camp Exposes Middle-School Girls to Engineering</i> C. Carroll; University of Minnesota - Duluth	
4:00 - 4:15 pm	<i>Reflection and Note Taking used in Active Learning</i> John Scheffler; UW - Stout	
4:15 - 4:30 pm	<i>Using a High Altitude Balloon Satellite Prototype Project for Systems Engineering Skills Development</i> J. Straub, R. Fevig; University of North Dakota	

October 5, 2012 | St. Cloud State University

Project-Based and Active Learning in Computer Engineering Education

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Abstract

Teamwork and creativity are critical in the profile of a new engineer. Thus, an exploratory innovation to develop project-based curriculum is being conducted, which leads to an active learning for Computer Engineering students. In this paper, student projects and technologies selected in Computer Engineering, and innovation in active learning are presented. The objectives of the project-based and active learning include applying virtual instruments and software on collaborative and industrial-relevant projects, teaching students all aspects of the design of a computer control system, expanding knowledge base of new technology, and preparing future engineers to face real-world problems. The curriculum is designed to be student-centered, interactive, and let students take command of learning. The development of student projects, including a novel Heart-rate Monitor with Embedded Systems, Real-time control of an Autonomous Robotic Vehicle, a Two-link Robotic Arm, and an Inverted Pendulum, is based on the application of virtual instruments and software. It has been shown that the innovative project-based curriculum development has a great impact on motivating students to embrace their responsibilities in active learning. Students' skills with hardware and software, comprehensive application and hands-on abilities, and creativity can be better cultivated.

Keywords: active learning, computer engineering education, project-based, student-centered

1. Introduction

There is a growing trend to encourage students to take a more active role in their own education. The emphasis is more on learning and it requires the instructor to incorporate more active and student-centered learning methods into their courses. These methods include collaborative, cooperative, problem-based, and project-based learning¹. It is well established that hands-on experience can significantly improve student active learning and interest level in the course materials. Therefore, the more active the students are in the classroom, the more engaged they are in the learning process, and the more they remember¹. Rather than giving students the solution to their problems all the time, we strive to teach them how to search for and construct complete answers and encourage students to pursue active learning activities. We would like to make our students capable of analyzing and evaluating on their own, promote active learning in and out of the classroom, and present students with creative problem solving challenges. This will guide them toward becoming independent thinkers and lifetime self-instructors.

Students learn when they are actively figuring things out, trying to teach themselves, not passively drifting through a lecture, expecting to be taught². Therefore, we design the class not around what teachers will do, but what the students will do, to let them take command of their own learning, and to teach Computer Engineering as a way of thinking and learning about the world around us. Additionally, teamwork and innovation abilities are critical in the profile of a new engineer. Thus, we are conducting an exploratory innovation initiative to develop these abilities through project-based courses, which are oriented to a group of Computer Engineering students. Hands-on lab and project-based learning have been introduced into the courses “Automatic Control Systems” (CEE 335) and “Embedded Systems” (CEE 445). That is, the emphasis of these courses is on design and implementation rather than theoretical analysis. More in-depth versions of the problems are assigned in the project design and lab assignments where students team up and tackle the problems using the knowledge that they have learned.

2. Development of Project-based Curriculum under Active Learning Environment

It is no longer acceptable for engineers to just analyze problems or mathematically derive models of problems; they must experience design, creativity, and innovation. Therefore, the objective of the innovation in Computer Engineering education is to apply virtual instruments (e.g., sensor, analog-to-digital converter, and virtual oscilloscope) and software (e.g., NI LabVIEW and MATLAB/Simulink), teaching students all aspects of the design and development of a computer control system in an active-learning environment, expanding the knowledge base of new technology, and preparing future engineers to face real-world problems. Consequently, students' skills with hardware and software, comprehensive application ability, hands-on and innovation abilities can be better cultivated. Also, students' capacities for teamwork, communication, leadership, and employment competitiveness can be strengthened. Thus, two project-based courses have been developed to fulfill the objectives as stated above.

2.1 Project-based Course I: Automatic Control Systems (CEE 335)

Automatic Control Systems (CEE 335) is a junior-level course, which covers classical methods of analysis and design for continuous-time and discrete-time control systems, analysis tools, software of MATLAB and NI LabVIEW, sensors, and computer analysis and simulation. The development of student projects as shown in Figures 1-3, including Real-time control of an Autonomous Robotic Vehicle, a Two-link Robotic Arm, and an Inverted Pendulum, which are based on the application of virtual instruments and software. One of the goals of the course is to integrate hands-on experiment with the theory of real-time computer control. The designed robots may perform predetermined assigned tasks, e.g., walking a plank turn around and following a lane while avoiding obstacles, or tracing capital letters accurately.

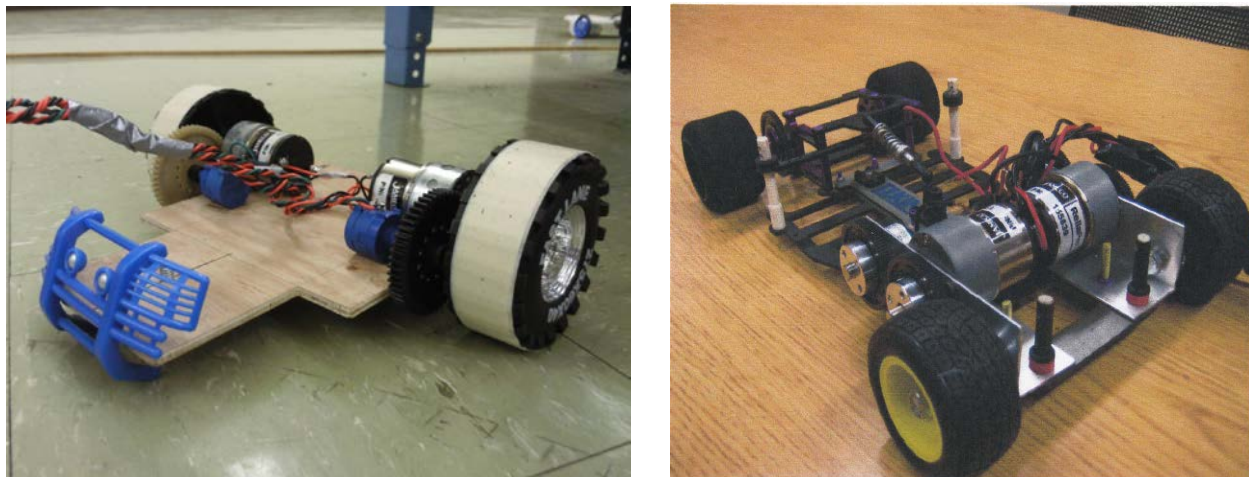


Figure 1: Project of Autonomous Robotic Vehicle.

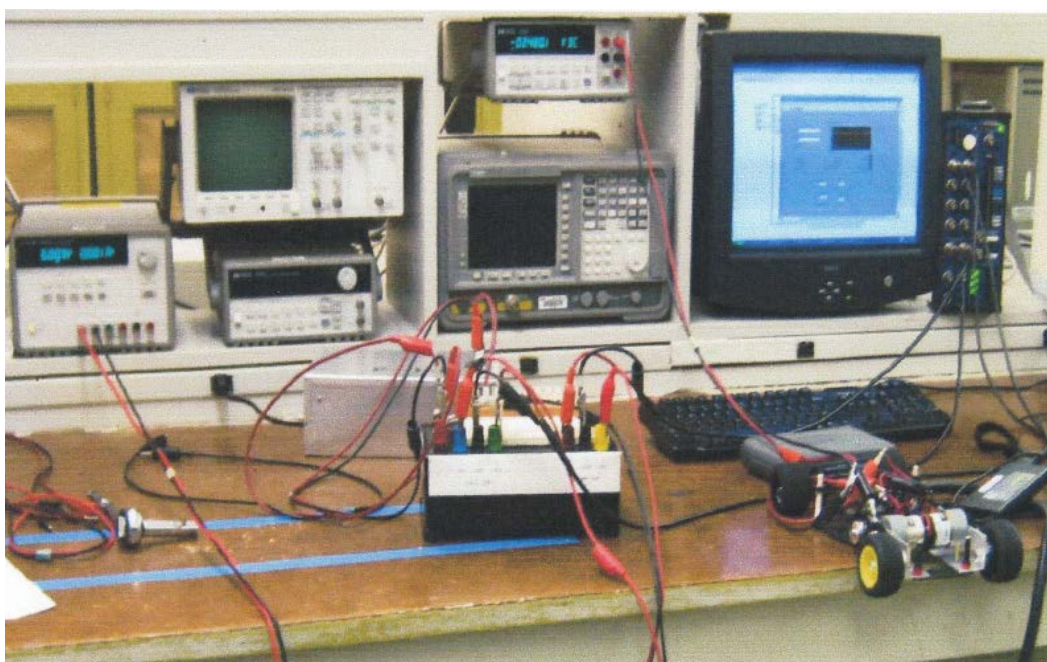
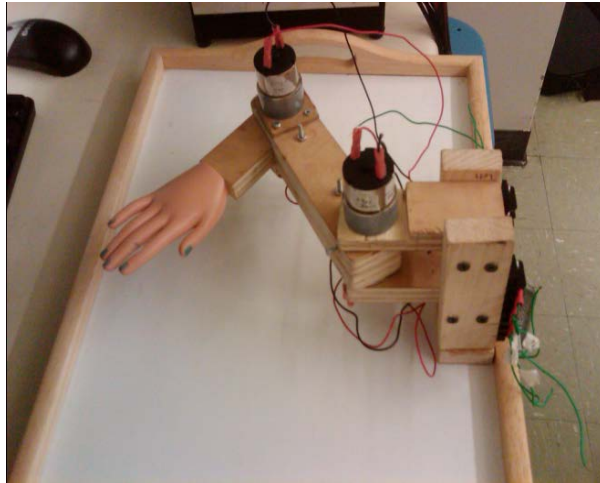
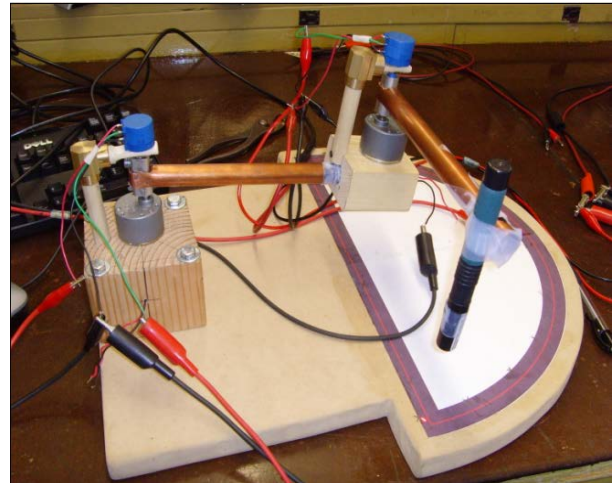


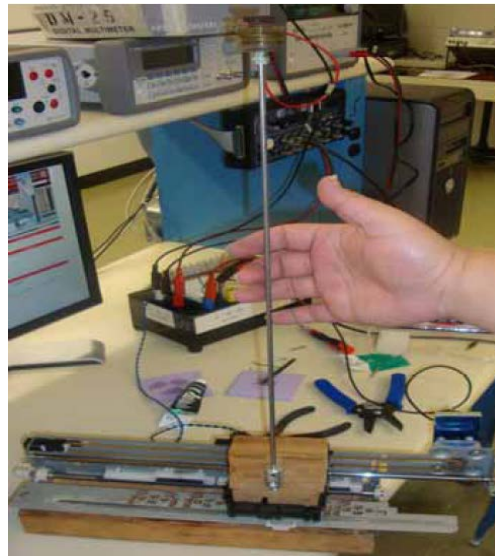
Figure 2: Active learning with virtual instruments and software.



(a)



(b)



(c)

Figure 3: (a) (b) Two-link Robotic Arm; (c) Inverted Pendulum.

The project is broken down into sub-components for the teams to work on during the creative laboratory assignments. That is, mechanical construction and test, electrical design and test, data acquisition system test, computer analysis and simulation, open-loop system test, closed-loop system test, and control design and realization by using virtual instruments and software. The teams are required to integrate the system together, devise a strategy to coordinate the motion, analyze the results, and produce a parts list and specifications.

The project also asks students to attempt to select proper components they might need from vendor's website that is beneficial to their future engineer career. Other learning activities developed for student projects contain:

- Complete electro-mechanical design, a formal test procedure by construction and trouble-shooting;
- Develop data acquisition and implementing real-time control of the autonomous robotics based on LabVIEW programming and MATLAB software.

Creative process is a critical part of engineering education, which can both motivate students and bring them deeper understanding of the study topics. The key point is that the projects and lab assignments allow for many different approaches, encouraging students to be creative in their designs. These assignments help students gain an exciting and valuable experience in project design that is closer to the real-world situations. While building is never a substitute for basic learning, it can motivate the study of difficult topics, allow students to test their theoretical understanding, and build confidence in their abilities.

The project is a comprehensive engineering activity, which involves the usage of multiple virtual instruments and software. Therefore, in order to inspire students to review the engineering fundamentals and experiments that they have learned, the instructor poses relevant questions on a PowerPoint in each class and students can win a prize for answering the questions correctly. The instructor then explains all of the questions, which can have tremendous positive benefits not only helping the students remember the concepts along with having a lot of fun, but also motivating with their own competitive spirit in learning. In addition, during the topic literature research, students are encouraged to collect reference material in order to help them understand the operation of the project and expand knowledge base of new technology.

Furthermore, the instructor requires students to write up their work into a formal report and then give an illustrated presentation to the class. In order to motivate everyone participating in the project activities, gently demand students to take responsibility for their own learning, and foster their management skills, all of the students in one group take turns being a leader and present the progress reports to the others. To establish an active learning environment, making class fun and entertaining with class games is also an important and effective method. For instance, when the project of Autonomous Robotic Vehicle is finished, a race is always held between each group's vehicle to inspire student's interest and enthusiasm for Computer Engineering and get them to be actively involved. Consequently, students are relaxed, involved, pay more attention, and learn better in the class.

2.2 Project-based Course II: Embedded Systems (CEE 445)

Another project-based course that has been developed at the University of Wisconsin – Stout is Embedded Systems (CEE 445), which is a new senior-level course. The class is designed to be student-centered, interactive, and lets the students take command of learning. During the first 4-5 weeks, the instructor presents the relevant knowledge about embedded systems, including microprocessor types, memory structures, interrupt control, external interfacing, embedded system sensing and security. The instructor uses directed questioning to get all students actively engaged and participating in the class, in order to encourage them to think, discuss, and defend their ideas. The effectiveness of this technique at producing a more interactive classroom and getting each student to intellectually grapple with the relevant issues has been confirmed upon teaching evaluations. On the other hand, undergraduate students get bored with theory and would like to see more practical examples. To overcome this problem, we have employed several strategies:

- Spend more time on examples and get benefit from graphs, demonstrations and videos;
- Solve selected sample problems in class, and present alternative approaches to have the students look at each problem from different perspectives.

Students then focus on the project design throughout the following weeks. One of the student projects developed in this course is a novel Heart-rate Monitor with Embedded Systems, which applies embedded system software and hardware design, verification, and implementation. Through LCD heart rate reading and alarm displays, it provides immediate notification of abnormalities in cardiac activity on a monitored patient, as shown in Figure 4. The designed monitor system is easily accessible, portable, and also has the benefits of low cost and low power consumption. In order to get the students better understanding the architecture of embedded systems, we use Cypress PSoC 5 development kit in the experimental projects to illustrate external interfacing, embedded sensing, memory structures, and interrupt control. At the beginning of the project, students are required to complete a literature research for the selected topic, and form their own study groups of 2-3 people. Effective use of study groups facilitates active learning by encouraging students to work on lab assignments and projects together – thus learning from each other. At the end of the semester, students in each study group complete a self-evaluation and peer-evaluation as part of the project grading. Individual lab assignments ensure that each student is able to apply engineering theory to real facilities. Laboratory activities developed for this course to assist project design include:

- Delta Sigma Analog-to-Digital Converter (ADC) to Character LCD;
- Toggle the rate of LED blinking based upon the position of potentiometer;
- Capacitive Sensing String Manipulation;

- Digital keyboard by using Digital-to-Analog Converter with operational amplifier.

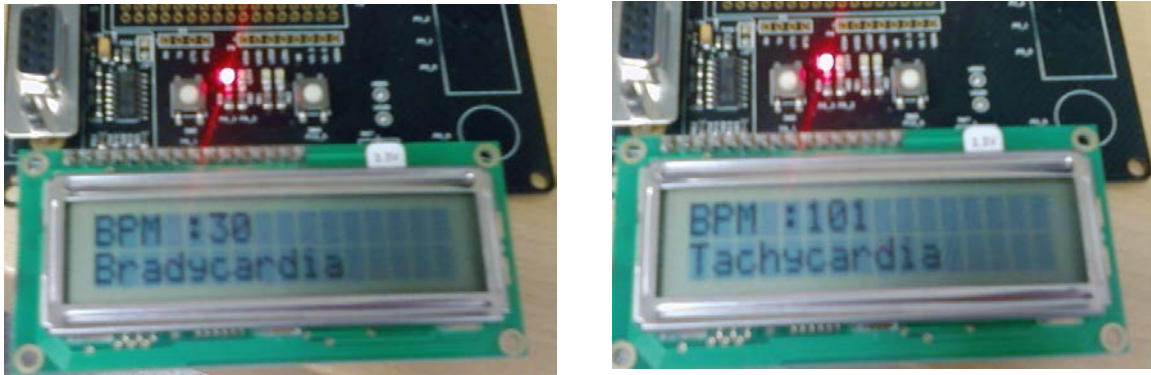


Figure 4: Project of a novel Heart-rate Monitor with Embedded Systems.

3. Conclusion

The innovative project-based curriculum development encourages students to think critically, discuss, learn from each other via working in group, gain valuable communication skills, and especially learn actively. Students have repeatedly commented on how the project-based and active learning courses have changed their views of Computer Engineering and its uses. It has been shown that our innovation has a great impact on activating student interest and enthusiasm for Computer Engineering and motivating students to embrace their responsibilities in active learning. Furthermore, student's skills with hardware and software, comprehensive application and hands-on abilities, and creativity can be better cultivated, as well as professional abilities of teamwork and leadership.

4. Bibliography

- [1] J.R. Goldberg, *Active learning in capstone design courses*, IEEE Pulse, vol. 3, 2012, pp. 54-57.
- [2] T. Chang and D. Chang, *A hands-on graduate real-time control course: Development and experience*, International Journal of Engineering Education, vol. 21, 2005, pp. 1083-1092.

Active Learning Strategies in a Project Management Course

Byron Garry
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Abstract

In our Electronics Engineering Technology program, the senior Capstone project is completed over two semesters, and the first semester course is entitled Project Management. In this course we teach the fundamentals of project management, as well as have the students plan and begin their Capstone projects. The instructor provides lectures on what are good project management techniques. Over several years, the course instructor has developed and uses several active learning student exercises to supplement the course lectures. These exercises are used to illustrate the project management information or skill that we want the students to use on their Capstone project. These active learning exercises are done in groups during what is ordinarily course lecture time. We assess and evaluate the students on their knowledge and use of project management theory with a test, and use the results to help us gather information on how well the students are meeting our program's ABET-ETAC Criterion 3 Student Outcomes.

Introduction

A senior Capstone course is a requirement for all Engineering Technology programs, under ABET-ETAC standards. Students must plan, carry out, and evaluate a group project to solve a technical problem. The Capstone project itself is the ultimate in active learning for undergraduate students. The students must define their problems and find answers on their own; using whatever resources they are able to gather. The course instructor acts as a technical resource only, not as a course lecturer.

In our Electronics Engineering Technology (EET) program, the Capstone project covers two semesters, and the first semester course is entitled Project Management. In this course we teach the fundamentals of project management, as well as have the students plan and begin their Capstone projects. In the course, the instructor lectures on what are good project management techniques, following the Project Management Institute's Body of Knowledge recommendations¹. Students are exposed to project management techniques in several courses in the EET curriculum, but this is the only course where they are studied in detail. We have used different textbooks over time, but we make sure the texts are consistent in their basic delivery of project management fundamentals.

Over several years, the Project Management course instructor has developed and now uses several active learning student exercises to supplement the course lectures. These exercises are used to illustrate the project management information or skill that we want the students to use on their Capstone project, and to give them a head start on the management of technical projects they will be doing in industry after they graduate. These ten active learning exercises are done in groups by the students, and include planning a picnic and a kitchen remodel, brainstorming, defining a project objective statement and priorities, finding a project's critical path with a PERT Chart, using Microsoft (MS) Project software, leveling resources, crashing a project, finding the Earned Value of an on-going project, and using risk analysis and a decision tree. This paper

shows the exercises' basic steps, and comments on how well, in general, they seem to work. We assess and evaluate the students on their knowledge and use of project management theory with a test, and use the results to help us gather information on how well the students are meeting our program's ABET-ETAC Criterion 3 (a) - (k) Student Outcomes. The results for several years are shown and explained.

Active Learning

Hattie, writing in "Visible Learning, A Synthesis of over 800 Meta-Analyses Related to Achievement", states "what teachers *do* matters"². The way that professionals approach their craft of teaching has a large effect on whether students learn, or not. Good teachers provide "multiple opportunities and alternatives for developing learning strategies based on the surface and deep learning some content or domain matter"².

Hattie also states that "it is what learners *do* that matters." Passive learning through lectures, which is still happening in the majority of engineering classrooms, is not the best way to learn. "...the aim is to make students active in their learning process – through actions by teachers and others – until the students reach the stage where they become their own teachers, they can seek out optimal ways to learn new material and ideas, they can seek resources to help them in this learning, and they can set appropriate and more challenging goals"².

Active learning is generally defined as any instructional method that engages students in the learning process. Active learning requires students to do meaningful learning activities and think about what they are doing, particularly in the classroom.³ The 'constructivist' theory of learning, that existing knowledge is used to build new knowledge, is based on the student being an active learner.⁴ Felder, et al., found in a review of literature that when the objective of learning is to facilitate long-term retention of information, or to help the students develop or improve their problem-solving or thinking skills, instruction that involves students actively has consistently been found more effective than straight lecturing.⁵

In 2004, Prince helped define active learning for the field of engineering education. Education research generally defines active learning as falling into one of several categories. Collaborative learning is when students work together in small groups toward a common goal.⁶ Experiential learning, or problem-based learning (PBL), is defined as when a problem to be solved is defined before all the relevant information is provided.⁶ The process of solving the problem guides what the students learn. In inquiry-based learning, the students are presented with a challenge and learn in the process of responding to the challenge.⁷

Prince found from his review of educational literature that active learning has benefits for student learning, but the assessment of those benefits is not always measureable and clearly defined. Some of the relevant benefits, such as students becoming more self-directed learners, are hard to measure. Other good student learning outcomes, such as measures of factual knowledge gained, can be affected by other factors outside of the active learning used in the classroom.

Jamieson and Lohmann's 2012 ASEE report "Innovation with Impact - Creating a Culture for Scholarly and Systematic Innovation in Engineering Education" makes several recommendations

for improving engineering education. Number 5 is to “Raise awareness of the proven principles and effective practices of teaching, learning, and educational innovation, and raise awareness of the scholarship of engineering education”⁸. There has been much study over the years on active learning and there is a “substantive body of knowledge of proven principles and effective practices in teaching, learning, and educational innovation.”⁸

Appendix B in the report⁸ states some of the results of surveys done from 2006 – 2008 on pedagogies used in engineering programs across the country. Respondents reported their use of active learning techniques, which can be broken down into subdivisions of collaborative, experiential, and inquiry-based learning. A portion of the results are shown in Figure 1. These results show that there is, in many cases, a majority of faculty using active learning in their classrooms, but there is still a large percentage that don’t. Perhaps more examples of how to do active learning in the classroom, such as those included in this paper, can help.

Pedagogies in Undergraduate Instruction	Practice Routinely	Practice lagging	Practice Occasionally	Practice Reluctantly
Collaborative Learning	57.8%	27.5%	13.8%	0.9%
Experiential Learning (PBL)	56.9%	33.0%	10.1%	0.0%
Inquiry-based learning	36.7%	42.2%	20.2%	0.9%

Figure 1. Portion of Survey Summary from Innovation with Impact Report

Active Learning Exercises in the Project Management Classroom

The Project Management course is a two credit course, officially set as one hour of lecture and two hours of lab. In practice, we set the course up to have a three-hour, once per week meeting, usually in the evening. This allows time for relatively short (20-40 minute) lectures, extended student exercises, and for students to work on the beginnings of their capstone project. Each weekly meeting has an agenda that the students see at the start of the class. Most exercises are done by groups of two to three, and use an example set of data or conditions, and the course instructor encourages changing membership in groups as the course progresses. Repeating fundamental project management tasks over several exercises, such as defining a project, and making a Critical Path Method (CPM) Chart, known more commonly as a Program Evaluation Review Technique (PERT) Chart, is used to reinforce that particular skill. For those exercises that are specifically on the Capstone projects, the project group does the work together. The exercises can sometimes take an hour themselves to do. Breaks are taken during the three-hour class time to keep the energy level high.

In the very first meeting of the semester, after a short talk describing the entire two-semester Project Management/Capstone sequence as a project in itself, the instructor projects a slide, a step at a time, of exercise #1. All students have planned a picnic of some kind or other, and are often surprised to realize that is the basis of project management.

Exercise #1: Plan a picnic. In groups of 3-4, make a plan for the preparation, implementation, and clean-up of a picnic.

- Appoint a recorder for the group, then brainstorm, and write down all the specific steps that need to be done to plan and implement a picnic that you can in 4 minutes.
- Shorten your list to about 10 items, and write those items on a Post-It, one item/sheet.
- Put the Post-Its© on the wall in time order from left-to-right when items must be done. Items that can be done at roughly the same time can be grouped together top-to-bottom.

On the second class day, after lecture from the textbook on project management principles, and a listing of what will be required for their own Capstone project Charter, the following sheet is handed out. Students are often puzzled by what these different parts mean, and why they need to be considered. Each group, after they post their plan on the wall, has to explain their reasons and budget. Each group has a different set of rationalizations, and it is good for students to hear each other's reasons.

Exercise #2: Kitchen remodeling project. For a kitchen remodel, make-up some reasons and numbers for each of these major characteristics of a project, to begin to create a project charter.

- Establish project objective, including length of project and budget
- Customer Need
- Project Resources
- Organizational Priorities
- Organizational Constraints
- Deliverables
- Then figure out 10-20 tasks needed to carry out these reasons, and use Post-Its© to put those tasks on the wall in order.

The third exercise, which takes place at week 3 or 4 when student Capstone groups and projects have been finalized, has been added just in the last couple of years to the course's set of exercises. Looking at the results of Capstone projects, through the eyes of the ABET Student Outcome assessment; the course instructor realized that many projects were having trouble throughout the length of the project because they had not defined well at the beginning what would need to be done. Again, each group shares what they have written, and each group is encouraged to take notes and consider adding tasks that seem appropriate to their own.

Exercise #3 Brainstorm your project

- Describe what you would like your project to do/be, what the goal of the project is:
- Tasks that need to be completed to accomplish this - at least 20 tasks - don't worry about the time order as you write out the tasks
- Parts to buy
- Things to design/develop
- Project priorities

Exercise #4 comes toward the beginning of the next three-hour class, and reinforces the learning on understanding the background and objectives of an example project. After a lecture on how to do forward and backward passes to find the critical path of a project, exercise #5 is done. This was the very first active learning exercise that the course instructor did in this course over ten years ago. It was an eye-opening experience for the instructor to see just how much fun students could have while they were learning an important project management tool.

Exercise #4: Project Definition. From the text for class, a project description: A new computer-controlled conveyor belt is an exciting project that moves and positions items on the conveyor belt with < 1 mm. The proposed project will produce a new system for future installations, and for replacement of those in the field, at a low cost.⁹ On back of the paper is the Work Breakdown Structure for the project, in the form of the first part of a Gantt Chart in MS Project software.

- Write an objective statement for this project. Generic form:
We will (project action) that (meets a published standard) *or* (satisfies a person or organization's requirements) *or* (fills a need) *or* (solves a problem) by (date) at a cost of (amount).
- What are the functional groups involved?
- Define a project priority matrix for this project, as shown in Figure 2
- Write out 5 major deliverables of the project and who the customer is for each

	Time	Cost	Quality
Constrain			
Enhance			
Accept			

Figure 2: Project Priority Matrix

Exercise #5: PERT (CPM) Chart

- Write out (Fill in the center column only to start) each of the Work Packages (list of 22 given) on Post-Its © as shown in Figure 3.
- Put them on the wall, in order indicated by the predecessor's column.
- Do a forward and backward pass to calculate the (ES), (LS), etc. to determine the length of the project and the critical path.

(ES)	ID #	(EF)
(SL)	Description	
(LS)	Duration	(LF)

Figure 3: Work Package

In the next class period, after the instructor demonstrates how MS Project works, and provides a step-by-step process sheet to follow, the students repeat exercise #5, using an industry-standard software.

Exercise #6: Microsoft Project. Homework is assigned, which the students start on during class time in order to have instructor help, input the Conveyor Belt Project and print a Gantt Chart.

The next class meeting, the instructor uses the MS Project Resource Graph to show that the given Conveyor Belt example does not have enough resources allotted to finish in the time first calculated. Students coming into this class session often feel from previous exercises that they have a good handle on how networks work. The resource loading problem then takes students by surprise, and forces them to see that there can be considerations that are overlooked the first time through.

Exercise #7: Leveling Resources. Following the procedure given by the instructor, in groups of two, use the MS Project leveling tools to:

- Level with constrained resources, and determine the new (longer) length of project.
- Add more resources (given by instructor), and level within slack (not possible).
- Determine for yourself what resources you have to add (at an instructor-given cost) to clear all resource constraints within the original length of project. What is the new (larger) project cost? Is this reasonable? Explain.

The lecture on the concept of project crashing, to reduce project time, and as a result increase project cost, is another problem that is often surprising to students. They often have a hard time grasping the steps needed to calculate the cost slope, and to learn to look at all the tasks that are present, to see how the time can be reduced at the lowest cost.

Exercise #8: Crashing. Students are given the tables⁹ shown in Figures 4 and 5. The instructor allows the students to calculate cost slope and max crash time, and then demonstrates the first step to crash the project by one day. Then the students in teams complete the crash to a total of four days.

Task ID	Cost Slope	Max Crash Time	Direct Costs			
			Normal		Crash	
			Time	Cost	Time	Cost
A			7	50	5	60
B			16	14	14	28
etc.						
Total				151		

Figure 4: Crash Calculations

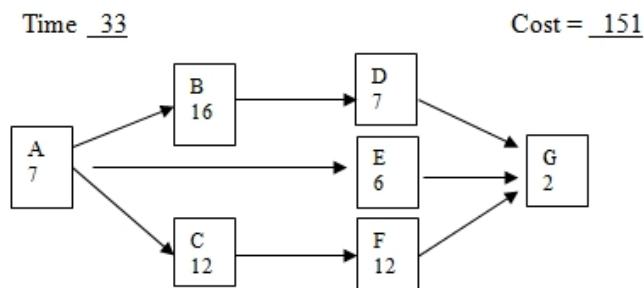


Figure 5: Starting Project PERT for use in calculating crashing

A single lecture on the terms used in earned value for a project, using MS Project terminology, is often too short and superficial for the students to fully understand the concepts. This engineering technology course on project management is meant to help the students understand the basics, and earned value is a fairly advance topic, but one that needs to be addressed. As long as there is example data that can be input to MS Project, and students can see the results of longer project time/higher project cost, the course instructor feels the exercise is useful.

Exercise #9: Earned Value Tracking. The instructor provides an example updated task completion for the first quarter (three months) of the Conveyor project, as shown in Figure 6. Using an instruction sheet and data provided by the instructor⁹, the students use MS project to

work through the first four quarters of the project and record the Schedule Variance, etc., as shown in Figure 7. After each quarter the students are asked: Discuss the state of the project - days and cost - and what will you, as a project manager, do (or not do) to keep the project on schedule. State details like add people to task X, add resources, change the plan, etc.

Activity	Planned Duration	Actual Dur.	Remaining Dur.
Hardware Spec	50	37	8
Kernal Spec	20	25	0
Disk Driver	100	13	87

Figure 6: Updated task times

Overall Project information after each quarter.					
	Total Project Days	Schedule Variance - SV	Cost Variance - CV	Projected Total Project Cost - EAC	Projected Variance at Completion - VAC
Baseline	530	0	0	\$1,027,200	0
1 st Quarter					
2 nd Quarter					

Figure 7: Summary of results of updated task times

The latest exercise added to the course, risk analysis and a decision-tree, came about because of a change in the textbook used in the course. It is another topic that needs more days of class set aside for the students to fully understand. A short, numerically-based exercise can point out the highlights of the concepts for students to grasp the basics.

Exercise #10: Risk Analysis and Decision Trees. The instructor gives the students a decision tree¹⁰, as shown in Figure 8. In addition is a description of the risk events, their cost, and their likelihood of happening. The students calculate the Expected Value of each branch and conclude which decision they would make.

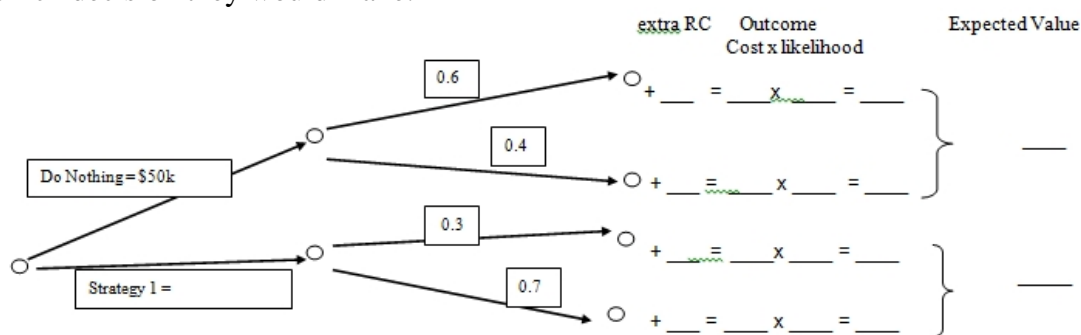


Figure 8: Risk Decision Tree

Student Outcomes

Student outcomes describe what students are expected to know and be able to do by the time of graduation. These relate to the knowledge, skills, and behaviors that students acquire as they progress through the program.¹¹

In our major, we chose to extend the definitions of regular Criteria 3 Student Outcomes (a) – (k) to include the specific program criteria for Electronics/Electrical Engineering Technology, which includes a requirement for project management. So we defined this student outcome as (n) EET graduates have the ability to apply project management techniques.

We assess this student outcome through a test about 2/3 of the way through the Project Management course. The test includes approximately 20% on short answers on project management terms, 40% on multiple-choice on project management theory, 10% on a crashing example, 10% on a decision-tree example, and 20% on generating a CPM Chart/Gantt Chart/resource loading diagram from given data. A bonus question of 5% asks how the resource loading conflicts in the given problem could be resolved.

Figure 9 shows the student outcome assessment results of the past eight years. As Prince noted, a direct connection between active learning and student performance is not always present. In fact, other factors come into play, as the descriptions of action taken when the objective's goals are not met, illustrate. The course instructor did not keep close track of when active learning exercises were added to the course over the years, so there is no attempt to correlate student success with how much active learning student exercises were used in that year.

EET 470	Student Outcome		Specific Course Outcome & Criteria		When	Tool
(n)	the ability to apply project management techniques		Articulate and use the tools and techniques used in modern project management. 80% of students score 80% or better on test.		approx. 11/1	Midterm test
Year	Student data	Pct.	Met objective?	Action		
04-05	10/14	71%	No	We will take some more time to review basic project management techniques before the test. In addition, we will add requirement for students to use some of these tools in prerequisite coursework, EET 380.		
05-06	17/21	80%	Yes	Met goal. We will continue to monitor.		
06-07	15/17	88%	Yes	Good results. Continue same procedure.		
07-08	15/25	60%	No	Due to the change to team-teaching in this fall's class, EET and MNET majors combined, less time was spent on each lecture topic and class exercises. Next year more time will be made to cover the topics from the text.		
08-09	23/25	92%	Yes	Good results. Continue same procedure.		
09-10	14/18	78%	No	Criteria not met. Class was left combined for PM theory, but separated for the Capstone Project launching portion of the class. Because of the resulting confusion in scheduling, we did not spend enough time on the theory of PM. Next fall will be EET-only for lecture, so we will make sure to spend more time on PM theory.		
10-11	15/16	93%	Yes	Good results. Continue same procedure.		
11-12	19/22	86%	Yes	Good results. Continue same procedure.		

Figure 9. Program assessment results for (n) EET graduates have the ability to apply project management techniques.

Conclusion

Active learning exercises in an engineering technology classroom can be a useful tool to use, to help students grasp and retain, in this case, important project management knowledge and skills that they will use in their careers after college.

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A pilot study: Motivating students to engage in programming using game-like instruction

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Abstract

To motivate students in a freshmen engineering problem-solving course in Spring 2012 semester to practice their problem-solving and programming skills, we developed a MATLAB-based computer programming project in which its handout/instruction was written based upon a gaming structure. By incorporating game-like elements into the project handout, we aimed to motivate students to actively learn an additional class-related topic and apply their knowledge and problem-solving skill to complete the project. The instruction was divided into three stages where students must pass a stage before they can move on to the next stage. The students get reward or points when passing each stage and get almost immediate feedback on their work at each stage. The pilot study was conducted to investigate student motivation on the use of the instruction that incorporates game elements, so called game-like instruction. Data were collected with the use of a modified version of the Instructional Materials Motivation Survey (IMMS) created by Keller. The instrument consists of four subscales: attention, relevance, confidence, and satisfaction. Results show that students were overall satisfied with the use of the game-like instruction and that the game-like project made materials more interesting and easier for them to understand the content. Overall, respondents were motivated to engage in the tasks. The game-like instruction may potentially be used to motivate students to practice their problem solving skill and to learn applications of MATLAB programming software. Nonetheless, further investigation needs to be conducted to evaluate the benefits of this approach to students' learning motivation.

Term: Game-like instruction, Gamification, Learning motivation, MATLAB.

Introduction

Encouraging students to actively learn class content and practice their problem-solving skill is important in education. Educational institutions nowadays encounter problems around student motivation¹. Motivation, one of the most important psychological concepts in learning², entices students to learn as well as to complete learning activities³. Lack of motivation can be a major obstacle preventing learners from concentrating on an instruction. The process of motivation includes getting and sustaining learners' attention, establishing the relevance of the instruction with learners' needs, building learners' confidence, and providing satisfying consequences⁴.

Active learning can be defined as instructional activities that involve students in doing things and thinking about what they are doing⁵. It is a process that provides students an opportunity to engage in learning and solving problem. One of active learning approach can be in a format of games, which associates learning with fun and allows for trial and error⁶. It can also encourage exploration and collaboration between students.

Many educators¹ suggest that lessons can be developed by incorporating game-like elements to enhance students' problem-solving skill. With the game-like lesson, an instruction incorporates the rules of game that students need to follow in order to accomplish an assigned task. Students will generally be rewarded for desired behaviors and punished for undesirable behaviors using points or tokens as a reward system⁶. By employing this approach in a learning activity or a classroom, students are encouraged to actively engage in the learning process. This would ultimately enhance their learning motivation.

Students' motivation to learn is important in their learning. Through the game-like instruction, educators can create an active learning environment where students can take a more active role in their learning. This pedagogical approach can be useful for enhancing students' motivation.

Methodology

The purpose of the study

The project aims to motivate students to practice their problem-solving skill using MATLAB computer programming software and learn related materials by incorporating game-like elements into its instruction. The study was conducted to investigate students' levels of motivation with the use of the game-like instruction.

Project handout/Materials

A computer programming project was developed and used in the engineering problem-solving course in Spring 2012 at a public teaching university. The project is to use MATLAB software to create musical notes and then play simple songs on a computer. This chosen project is used to interest students in working on a real-world application using a topic on music that they can relate to. This project was an optional assignment where students can work in a group to earn extra credits.

The project instruction was written using a gaming structure. It was divided into several stages where students must pass a stage before they can move on to the next stage. Each stage has its own tasks and timeline. The tasks in a higher stage were built upon the tasks in a lower stage. These stages were used to guide students in learning materials by themselves along the project in order to complete the assigned tasks and finish the project.

To pass a stage, each group must submit their assign task (programming code) to an instructor which acts as a game master. When passing a stage, each group got new tasks for the next stage and reward or points. The bonus points were also given for the first three groups who passed each stage.

At the beginning, each group got three tokens where each token represented one wrong code submission. If submitting an incorrect code, the group lost one token but it got the feedback on the code from the game master to help fix the code. The group would be disqualified from the game if it used up all the tokens or if it did not meet the timeline for each stage.

During the project duration, each team can interact with a game master as much as they want either in person or through email in order to clarify the assigned tasks or submit their code. When communicating via email, the game master typically responded within four hours during business hours to provide an almost immediate feedback and interaction between the instructor and students.

Procedure

The project duration was approximately two weeks and every student in class had access to the instruction of the first stage including the game rules. At the end of the project, students who finished the project were asked to complete the survey. The study was conducted to investigate student motivation on the use of the instruction that incorporates game elements.

Assessment instrument

The assumption of learning motivation shadows the ARCS Model, a four-factor theory that measures individuals' levels of motivation developed by Keller⁷. The model includes four factors: attention, relevance, confidence, and satisfaction. First, attention is a strategy for arousing and sustaining a learner's interest³. In order for learners to be motivated, instructional materials may include techniques to stimulate a sense of exploration in learners. Relevance is related to how well the instruction meets a learner's needs. Instructional materials must show that contents are important to learners and relate to their personal learning goals². Confidence refers to the learner's attitude toward success or failure. This factor incorporates variables that relate to students' feelings of personal control and expectancy for success. Finally, satisfaction is positive feelings about students' learning experiences. Learners need to be satisfied with the learning experience in order to maintain their motivation. Rewards can be used as motivational feedback to sustain motivation as long as the rewards are important to learners⁴.

The Instructional Materials Motivation Survey (IMMS) instrument created by Keller⁸ was used to gather the data. The IMMS instrument consists of four subscales: attention, relevance, confidence, and satisfaction. The IMMS instrument was designed to assess how motivated learners are by a particular type of lesson². It contains 36 questions with 5-point Likert-scale items that measure learners' motivational reactions to self-directed instructional material. Each question on the IMMS instrument corresponds to one of the ARCS model components.

The IMMS has a documented reliability coefficient of .96 and is considered a valid instrument⁸. The instrument was slightly modified to assess how the use of the game-like instruction affects motivation. The modified instrument consists of 36 Likert-scale items and two open-ended questions. All Likert-scale items continue to range from *Not true*-1 to *Very true*-5.

Data Analysis

Descriptive statistics were calculated before 10 negative items were recoded to obtain the mean scores of the motivational scales. Two open-ended questions were coded using an open coding technique.

Results

Since the project was optional, 27 out of 80 students decided to participate and only 14 students finished the project and complete the survey.

The highest mean score was the question asking participants whether they felt good to successfully complete the project (M (mean) = 4.93). They indicated that completing the project gave them satisfying feeling of accomplishment (M = 4.86). They also agreed that tasks assigned in the game-like instruction were important (M = 4.79) and relevant to what they have learned in the class (M = 4.71). Most students expressed that feedback from the faculty helped them feel rewarded for their efforts in completing the project (M = 4.64). The mean scores of the two questions: “The stages of the instruction and the end product helped to hold my attention” and “It was a pleasure to use such well-designed lesson.” were the same (M = 4.57). They also agreed that this type of lesson (M = 1.21) and its structure (M = 1.29) were not boring.

Furthermore, students were asked what they like about this project. Thirteen out of fourteen students responded to the question. Some students thought that the project with the game-like instruction made materials more interesting and easier for them to understand the content.

“It is fun, creative, and challenging.”

“It gave me an opportunity to make up for lost points and showed me an interesting function of MATLAB”

“The way it is presented is very clear. It also shows the real implementation of MATLAB at this level.”

“When I can see it all come together in the end and work properly. That's the best part”

The participants were also asked to provide suggestions for the improvement of this instructional approach. Four of them did not provide any suggestions for an improvement. Valuable suggestions were as follows:

“You can add stage 5 which prompt the user to choose the music that he or she likes to play.”

“I think the game is a good one, but more of it must be present to the class because it depicts real world knowledge.”

“maybe combine stage 2 and 3 as stage 3 is really simple.”

“Possible break it up into even smaller segments.”

Discussion

Based on the findings, it can be expressed that overall participants were motivated by the use of the game-like instruction and were satisfied with this type of instruction. They agreed that the instruction were related to the concept of MATLAB programming they have learned in their class and a real-world application. The findings imply that the participants were motivated to actively engage in the tasks and that the instruction with a gaming structure could help hold students' attention to the lesson, which would help sustain their motivation to learn actively. However, this type of instruction may evidently not appear to make students feel more confident in their learning ability.

Overall, students liked the game-like instructional approach. They thought that this teaching approach made the subject more fun and challenging to learn. Obviously, they liked that they could earn extra credit while having fun.

In addition, it is interesting that the responses on suggestions for an improvement of this instructional approach varied. Some mentioned that the instruction should be broken down to smaller segments, but a few students thought that stages can be combined. It is not surprising because the diversity of students can form different perspectives on a particular instruction.

Remarkably, considering the number of participants, the extra credit given did not entice students to participate in this activity. Such incentive only attracted those who deprived for additional scores. It would be interesting to see responses when this type of learning activity is offered as a requirement.

Conclusion

The findings suggested that this teaching approach can be used to foster students' motivation to learn as well as to encourage students to actively engage in their learning. This pedagogical manner was a pleasurable way to learn a new concept. The game-like project may potentially be used to motivate students to practice their problem solving skill and to learn applications of computer programming software. It would help enhance students' learning experience. Further investigation needs to be conducted to evaluate the benefits of this approach to students' learning motivation.

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Design and Manufacture of Polymer Components for an Ink Pen: an Example of Project Based Curriculum in Engineering Technology at UW-Stout

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Abstract

In this paper we describe the Engineering Technology Program at The University of Wisconsin Stout. The project based learning aspect of the program is emphasized by describing an example capstone student project wherein the components for an ink pen are designed. This project exemplifies the design, project management, and manufacturing emphasis of the program of study. The project also demonstrates by example, the excellent learning experiences that can be provided to students, when industries are willing to partner with the university.

Overview of Engineering Technology at UW Stout

The University of Wisconsin-Stout Bachelor of Science Engineering Technology (BSET) degree has a long history of success. Many of the current BS degree programs at UW-Stout began as Engineering Technology (ET) concentrations that grew into successful individual programs. There are six concentrations in ET: Mechanical Design, Plastics, Electrical, Facilities, Production Operations, and Nanotechnology. Degree completion requires one hundred twenty four credits of coursework; fifty-one General Education credits, twenty-three Professional Studies credits, and fifty Core or Concentration credits. Completion of a three credit capstone course is required in the Core Concentration credits¹. The UW-Stout ET program consisted of 417 students during the 2010/2011 school year.

All UW-Stout ET students must meet the same General Education and Professional Studies requirements. Required General Education courses consist of an emphasis in analytical reasoning and the physical sciences and include calculus, statistics, chemistry, and two semesters of physics. The Professional Studies area differentiates the BSET degree from UW-Stout's three BS Engineering degrees. Studies in this area include management, accounting and marketing related courses. Only three additional business courses, totaling nine credits, are needed to complete a Business Administration Minor. Many students take advantage of this opportunity.

Required Core Concentration courses for all ET students include Introduction to Fluid Power, Electricity/Electronic Fundamentals, and Engineering Graphics Fundamentals. Facilities students take Architectural Graphics using Revit instead of Engineering Graphics Fundamentals. The Electrical Concentration Core courses differ from the other ET concentrations. The courses required for completion of this concentration are taken from the computer science and electric

disciplines. Students in the remaining five concentrations take additional common courses consisting of an emphasis in materials and manufacturing processes. The common courses are: Plastics Materials and Processes, Material Removal and Forming Processes, and Joining and Casting Processes. The remaining credits consist of core area specific coursework and four to nine selective credits varying by concentration.

Approximately sixty percent (about 250) of the ET students are in the Mechanical Design concentration. The other five concentrations range in size from ten to forty students. In 2010/2011 there were sixty three total ET graduates. The employment rate for these graduates was 98% with one looking for employment and three deciding to continue their education². Graduates find employment in small to large corporations, mostly located in the Midwest, particularly Wisconsin and Minnesota.

The Plastics Concentration began in the 1990's and has historically been the second largest concentration, typically consisting of about forty students. The plastics core classes are Chemistry of Polymers, Injection Molding Technology, Extrusion Technology, and Thermoforming and Blow Molding Technology. Course content consists of both theory and application based curriculum. The well-equipped plastics lab uses actual processing machinery for studying plastics manufacturing processes. The Plastics concentration is closely related to the Mechanical Design concentration. It is very common that Mechanical Design students also complete a Plastics concentration, requiring only an additional sixteen credits of coursework.

Example Capstone Project: Design and Manufacture of Ink Pen Components

In the spring of 2011, Wendy Stary, UW-Stout Engineering and Technology Department faculty member, Greg Gryskiewicz, President of Alliance Plastics Corporation of Chippewa Falls, WI³, and John Schultz, UW-Stout ET program director, brainstormed project ideas for a product to produce as an extruded item. This item would have practical applications for teaching and learning, as well as serve as a "give away" item to UW-Stout campus visitors. Ideas ranged from producing pens to hoola hoops. A primary goal was to develop extrusion tooling that could also be utilized for learning purposes in multiple courses serving ET, Plastics Engineering (PLE), Manufacturing Engineering (MfgE), Packaging, and Applied Science students. The pen was chosen because it fit all of the established criteria and also provided an opportunity for incorporating additional plastics and assembly processes.

Upon final selection of the pen product idea, Wendy Stary contacted Scott Coulson at Coulson Precision Tooling of Chippewa Falls, WI⁴. Scott Coulson agreed to donate the design and manufacture of a die and pin that fit an existing UW-Stout die adapter, a calibrator was also donated. The die and calibrator were completed by Coulson Precision Tooling late in the fall 2011 semester.

In early February 2012 several project ideas were proposed to ET capstone course students. The capstone students choose their capstone project, they are not told to work on specific projects.

One of the project ideas proposed and actually chosen by an ET Plastics capstone group was the pen extrusion project. Project group members met with John Schultz to define the project problem statement. The project parameters were intentionally vague to allow for design creativity. The group expanded on the details and created a Gantt chart to assist in tracking their project progress. The capstone group kept a journal detailing their activities.

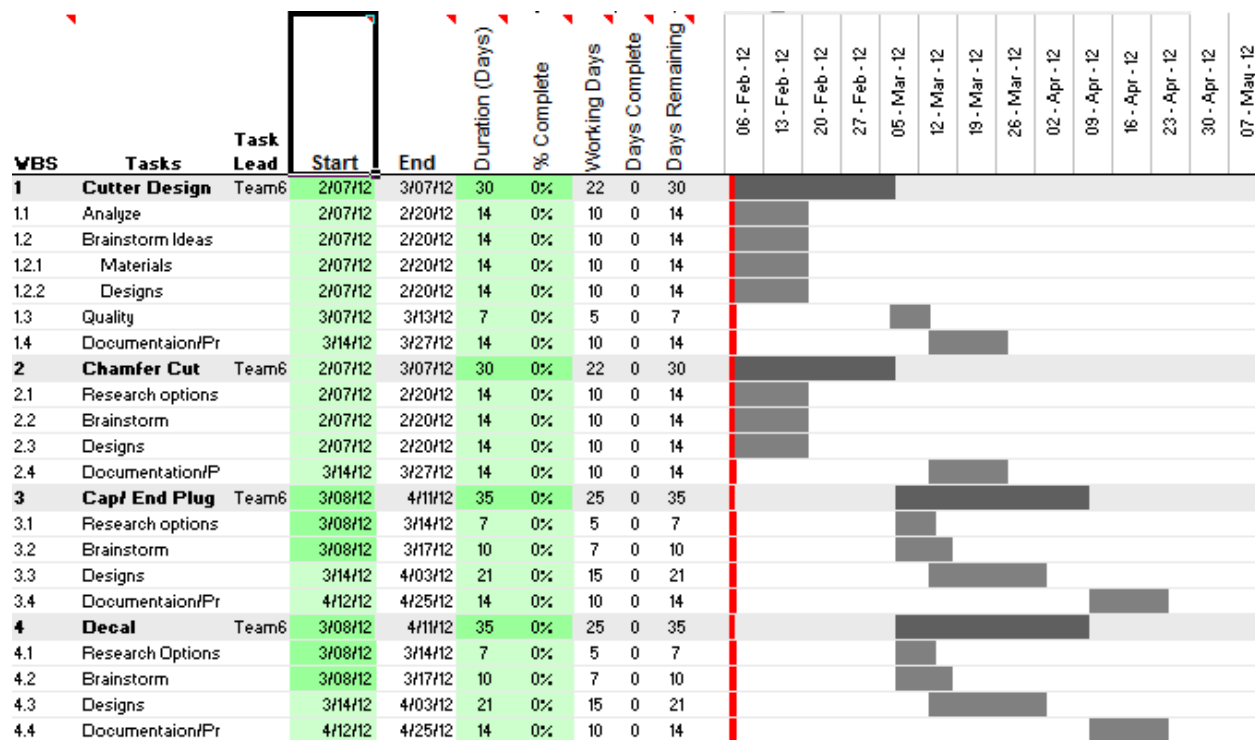


Figure 1: Gantt chart initially developed by team members for the development of the pen assembly.

The initial pen project idea was to extrude a thick wall barrel and machine a radius on one end and a taper on the opposite. An ink cartridge would press fit into the barrel and the pen would be ready to use. The design was changed within the first two weeks to create a more complex pen. The new pen consisted of a thin wall barrel with an injection molded cap, end plug, and cartridge adaptor. A second group of senior ET Plastics students in an independent study extrusion course concentrated on process development for the barrel. Both groups met frequently to discuss progress, materials, design features, and other issues.

After initially sketching the pen parts, group members met with Dr. Adam Kramschuster, Program Director for the PLE program, to verify that the parts could be molded in the UW-Stout plastics lab. The group also decided to build a family mold for injection molding to produce all three parts at one time. Building this tool enhanced the capstone experience. The capstone group focused on the molding aspect and worked closely with the extrusion group. One of the first decisions was to determine which plastic material would be used to make the parts. The first choice was polycarbonate (PC). Polycarbonate met critical processing criteria as grades were available for both injection molding and extrusion. It provided the physical properties

required for the pen barrel, and also surpassed the necessary aesthetic criteria when produced with a semi-transparent colorant. RTP Company of Winona, Minnesota⁵ supplies resins as required at no charge to the UW-Stout plastics lab. Several grades were available, but the sizing tool was unable to produce consistently round parts within tolerance for a press fit ink cartridge. The extrusion group worked closely with Joel Soenksen at Teel Plastics, Inc. in Baraboo, WI⁶ as they tried to solve the roundness issue. Ultimately they learned the tools available were more readily adapted to other resins. At that point, the extrusion and injection molding groups made the decision to revise the design to utilize polypropylene as the material for all pen parts.

The next project step involved research on various aspects of injection molding. This included processing conditions, shrinkage, cavity specifications, runner systems, ejector methods, tolerances, assembly, and more. By the first of March, 2012, Nolato Coutour of Baldwin, WI⁷ donated a mold base and offered their tool room for machining the tool. Individual mold inserts were designed using SplitWorks⁸. Detailed three dimensional cavity drawings were completed near the end of March and Mold Flow⁹ simulation was used to verify the injection process. The flow simulation showed that it would be difficult to mold three distinctively different parts in a single shot. Various options were researched and a final decision was made: add runner shut offs to the mold. This allowed all three parts to be molded using one tool and one set-up, yet it was possible to produce individual parts using the appropriate processing conditions. This was very cost effective as set-up time and tool costs were reduced. The injection molding (capstone) group maintained contact with the extrusion group who were still having difficulty making consistently accurate pen barrels. The extrusion project group received technical consultation on the extrusion process from both John Schultz and Wendy Stary, and it was ultimately determined that the extrusion tooling was most likely not sized correctly for the application. Both groups decided to continue with the injection molding tool. The extrusion group completed research on tooling specifications. April resulted in a flood of activities for the capstone molding group. They conducted finite element analysis by applying extreme loads on the press fits, used UW-Stout's Stratasys Fused Deposition Method (FDM®)¹⁰ rapid prototyping equipment to create samples of the barrel, end cap, pen cap, cartridge adaptor, and the mold inserts.

Two members of the group machined the aluminum mold inserts at Nolato Contour and all the required documentation

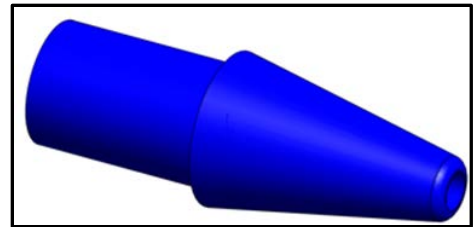


Figure 2: Final cartridge adapter design

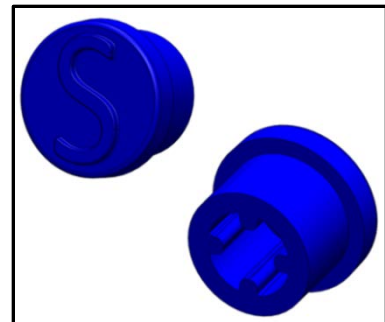


Figure 3: Final end plug design

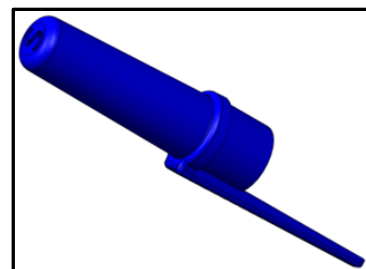


Figure 4: Final pen cap design

was updated as required. On May 2, 2012 the tool was put in an injection molding machine and the sampling process began. All four group members were present and experienced the thrill of success as a result of their hard work and perseverance. All three pen parts were molded to the planned specifications. A small quantity of each part was molded for future use.

On May 3 the group gave the final formal project presentation to classmates, instructors, and corporate sponsors at the capstone presentation meeting. A project poster was created and members attended the Engineering and Technology Department Exposition the night before commencement to display, discuss, and defend their work. The department exposition is attended by faculty, students, and the general public. The final report was submitted to the instructors on May 7. All four group members are currently employed in the plastic injection molding industry: two at Nolato Contour, one in southern Wisconsin, and one in Indiana. All are enjoying their employment and undoubtedly the capstone experience was instrumental in opening the door to the beginning of their careers.

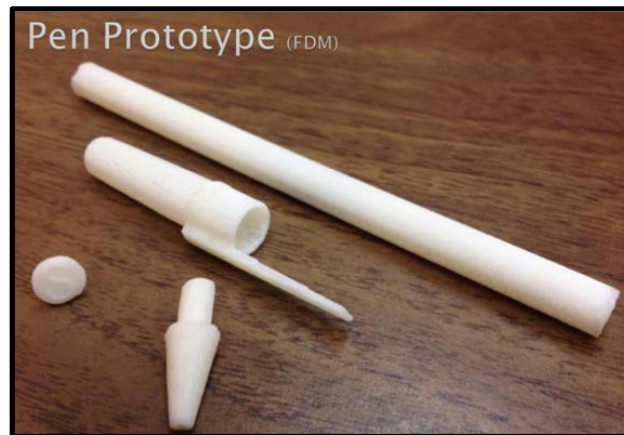


Figure 5: Pen assembly prototype



Figure 6: Mold insert prototype

Description of the Capstone Course¹¹

The capstone course is designed to compile many topics learned throughout the undergraduate curriculum into an application which typifies an entry level engineering design project. Great effort is taken to make this experience resemble actual industry practice in order to prepare the students for work place success. The course learning outcomes for the capstone course include the following:

1. Individual achievement through group success.
2. Independent research applied to design problems.
3. Develop project management skills for design engineering projects.
4. Develop written and oral communication skills in an engineering project context.
5. Produce industrial grade documentation packages including engineering drawings, appropriate detail, tolerance, and structured bill of material (BOM).
6. Manufacturing planning as part of design including concurrent engineering practices and informal design for manufacturing (DFM) procedures.
7. Development of product support materials such as operator and maintenance manuals, and assembly instructions.
8. Apply engineering analysis techniques and documentation of the analysis in an industry accepted format.
9. Finite element analysis (FEA) application, including the concept of benchmarking for results verification.
10. Economic analysis of engineering design projects.
11. Market study and customer needs assessment.
12. Presentation of project summary and results in research poster based format.

The format for this course is somewhat unconventional in that lectures and presentation of new material are few and interspersed throughout the semester. The primary role of the instructors is to act as engineering managers, facilitate project progress and advise students of typical industry practices as they apply to the individual projects. The lecture material includes application of prior course topics in a professional setting, including specific lecture topics of: project management, teamwork, concurrent engineering practices, concept generation techniques, design analysis presentation, documentation and BOM formats, tolerances, and introductory FEA techniques.

During many of the scheduled course sessions, the student groups, assigned by the instructors may work independently on their chosen projects. Course faculties remain available to coach the student groups during these sessions. In order to maintain a certain level of continuous progress throughout the semester, several tactics are employed. First the student groups are required to develop and submit a project schedule in the typical Gantt chart format early in the term. The schedule is reviewed by faculty and may require revision if unsuitable. Secondly, on various dates throughout the semester, each student group makes a presentation to the rest of the students

in the class, providing an update as to the status of completion of their project. Along with the presentation, which is useful in utilizing peer pressure to keep all groups from excessive procrastination, the groups submit written documentation appropriate to the project theme and degree of completion. For example, during the first design review, the project schedule and the definition of the project are provided. During the second design review student's hand in three or more concept designs and provide a rationale for the concept that they have chosen to pursue. Latter presentation and assignments include engineering analysis, and sample documentation.

The preliminary stage presentations allow for practice and training in presentation skills and appropriate fielding of questions. The preliminary project work allows for instructors to critique the approach taken and provide timely feedback to the student groups. This process has proven to help foster improved project performance by all groups. During the last week of class, the groups make formal presentations to the class, invited faculty, program advisory board members and industry sponsors. This presentation is defined in terms of allowed time (+/- 3 minutes), formal dress, and a question and answer session following each presentation. Each member of a project group is also required to provide one hour of attendance during a College of Science Technology, Engineering and Mathematics (STEM) project/research poster session.

Industry Partnerships

One key element of the success we have experienced with our capstone course is that the majority of our capstone projects represent solutions to real current problems faced by a host of partnering industrial firms. In recruiting industry partners to participate in this program our faculty try to assure possible sponsor companies of the potential interests they have that can be served through participation. Some of these interests include:

1. Minimal costs to have a student group develop a paper design solution.
2. Gain a "fresh" look at the problem without a viewpoint of the historical approaches.
3. Development of "proof of concept" prototype for materials cost and mentoring investment.
4. Low risk to company as minimal company resources invested.
5. Sponsoring projects assists in recruiting efforts by exposing students to the type of work done at this firm.
6. Lower priority projects that may otherwise be delayed get addressed.

When setting up industry sponsors projects we define a responsibility for the company to provide a mentor through which the student group can obtain information necessary to successfully develop the project.

In order to facilitate a sustainable interest by industry in sponsoring these capstone projects, we employ a number of strategies. Department faculty members are encouraged to present the capstone sponsorship and explain the possible benefits (outlined above) to industry representatives at every opportunity. Faculty members often visit with companies that have an interest in hiring graduates, coop students, and for class tours. Current students that have had very positive cooperative educational experiences are encouraged to propose projects relating to the company and department for which they have done the coop. An active industrial advisory board for programs is maintained that meets bi-annually. These members are repeatedly exposed to the capstone experience. Former students that are intimately aware of the program often contact the instructors with ideas for future projects. The outreach organization that represents the STEM College at UW Stout, known as Stout Technology Transfer Institute (STTI),¹² continually assists regional companies with manufacturing improvement and training programs. This model organization for technology transfer has assisted in the development of many industry sponsored capstone projects.

Conclusion

In this paper we have shared a discussion of project based learning employed by our Engineering Technology program. The paper reviews a specific example project for the design and manufacture of several components needed to complete an ink pen product. The project was completed within the framework of our program capstone course and utilized extensive involvement from some of our industry partners. We hope that by sharing the details of this example project and our capstone course layout, others within the Engineering Technology community will be inspired to also employ or increase the use of project based curriculum and industry partnerships to enhance student preparation for the workforce.

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Development of Low-Cost, Hands-On Lab Experiments for an Online Mechanics of Materials Course

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Abstract

Online education has expanded quickly in recent years and offering an engineering curriculum online has been limited by the ability to replicate lab experiments that are integral to some courses. Some approaches to lab experiments in distance education or online courses have been attempted including recording video of lab experiments or creating simulations of laboratory experiments that run virtually via the internet. This paper outlines the development of a set of inexpensive, transportable lab experiments for students in a Mechanics of Materials course offered via distance education. The set of labs were developed to allow for hands-on learning with a kit of supplies and a list of experiments that students could perform at home using readily available materials. The labs were developed using materials that had properties which mimicked the behavior of traditional materials like steel or aluminum, but exhibited those behaviors at much lower applied loads and stresses. Most labs allowed for actual data to be taken and analyzed while a few labs demonstrated the concept qualitatively. These labs were initially integrated into an existing Mechanics of Materials course offered via audiographics and will be offered in conjunction with an online course in a coming semester.

Introduction

Engineering education is increasingly moving to nontraditional delivery modes, especially online delivery. During the fall of 2009, over 5.6 million students were enrolled in at least one online course, a 21% increase over the previous year.¹ As online education expands it is increasingly important to ensure the quality of instruction is at least equivalent to that offered via traditional methods. In the online environment it is not only difficult to present complex engineering concepts, but it is a huge challenge to offer any experimental laboratory experiences. This paper reports on the development of a set of low-cost, hands-on lab experiments that can be performed at home as a part of an online mechanics of materials course.

There are four widely-accepted methods to deliver laboratory experience to online students. They are virtual simulations, on-site labs, simple home-based labs, and remotely accessed labs.² Little has been published regarding online labs for a mechanics of materials course. Bhargava et al. used virtual labs to deliver a laboratory experience to mechanics of materials students.³ Alexander and Smelser used a combination of several lab delivery methods to deliver a distance mechanics of materials lab.⁴ The approach taken in this paper was heavily geared towards simple home-based lab experiments.

This paper begins with background information as to why the course and labs were developed online for the UW Colleges. The outline of the course associated with the labs is then discussed followed by the details of the labs. Student and instructor feedback are then presented. Finally, some conclusions and future work are discussed.

Background

The University of Wisconsin Colleges (UWC) is part of the University of Wisconsin System. The UW Colleges are composed of 13 two-year campuses geographically dispersed across the state of Wisconsin. The UWC mission is to prepare students for success at the baccalaureate level of education. The University of Wisconsin Colleges offers the first two years of general education including calculus, chemistry, and physics as well as introductory engineering courses and the engineering mechanics courses. The curriculum is offered via face-to-face instruction at five of the campuses and via distance education (DE) to the other campuses. Prior to 2007, the DE courses were offered synchronously using either audiographics or compressed video. Audiographics connects students via a telephone conferencing system and a web meeting using Blackboard Collaborate. The faculty member controls the computer and the meeting in real time. Compressed video is a teleconferencing system where the faculty member can connect via video to up to five remote campuses. Both methods require students to attend class at a specified time and day. The students must be physically present at their campus to attend the course.

The UW Colleges recently joined with the University of Wisconsin – Platteville (UWP) to offer a collaborative engineering program. In this program, the UW Colleges offer the lower-level courses for an engineering degree and UW Platteville offers the upper-level engineering major courses. The program would target place-bound students unable to attend engineering classes at UWP by using online streaming video to deliver the necessary content. In response to this collaboration, the UWC faculty determined that the current course offerings would need to be developed for an asynchronous online delivery mode. Over the last four years the faculty have migrated all of the UWC engineering courses to the online environment. This paper discusses the development of lab experiments that can be done at home as a part of an online mechanics of materials course.

The mechanics of materials course considered in this paper is part of the typical undergraduate engineering mechanics sequence including statics, dynamics, and mechanics of materials. Topics covered include stress, strain, axial loads, torsion, bending, transverse shear, transformations, beam deflection, and buckling. A requirement of the UW Platteville mechanics of materials course is a lab component. The course had been previously offered at the UW Colleges both with and without a lab component depending on the resources at each campus. Given the collaboration with UWP, the UW Colleges needed to offer the course with a lab via online delivery. Several options for the lab were discussed including a mobile lab travelling the state, bringing students to a central lab a few times each semester, and virtual online labs. Ultimately it was decided to create inexpensive lab experiments students could perform at their home.

The pilot offering of the mechanics of materials lab developed for online delivery lab was actually a part of the existing audiographics delivery in the fall semester of 2011. These students were located at several campuses across Wisconsin and did not have access to any other labs.

Previously, the course was offered via audiographics with no lab component and students were expected to take the lab portion of the course after the transferred. For the first offering of these at-home labs, students were given the labs and asked for feedback on the experiments. The following section outlines the lab experiment created for the course.

Lab Experiments

There were a total of 10 labs initially developed for the course; most of which consisted of three primary components. The first component was direct measurement of physical properties, where students would use their measurements and apply the concepts and equations from the lecture to perform calculations and derive physical meaning. Secondly, the calculated values could be compared with published values for that material property; or the measurements could be compared with the predictions from theoretical equations. The final component for some labs included observation and/or demonstration portions where students were observing or predicting the effects of a behavior, without making measurements or calculations about it. Students were encouraged to watch videos of similar experiments being performed in a materials testing lab, however, these labs were not based upon data collected during a simulated lab. Table 1 lists the lab experiments and which components were utilized for each.

Table 1: Lab experiments with utilized components

Lab Title	Practical Measurement and Calculations	Comparison to Published / Theoretical Values	Demonstration / Observation of properties w/o direct measurement
Error Analysis	X		
Allowable Stress	X		
Tension	X	X	X
Creep	X		
Shear Modulus / Thermal Expansion	X	X	X
Stress Concentration			X
Angle of Twist	X	X	
Beam Bending	X	X	
Deflection	X	X	
Buckling / Strain			X

The following sections describe each lab experiment including the objectives and basic setup of the experiment.

Lab 1: Error Analysis

The first lab considered experimental error analysis. The objective was to understand the fundamental types of errors and to learn how to properly account for errors in measurements and calculations. In this lab, students were introduced to an overview of how errors occur, how they can propagate, and how they are measured in the lab. This was a critical initial lab since the

subsequent experiments have a high degree of variability. Students learned how to account for errors in equations and how to estimate errors in their work. Students then applied error analysis techniques to evaluate variability in the thickness, diameter, and volume of a set of 30 pennies. The materials used for this lab were supplied by the students and included a digital caliper and 30 pennies.

Lab 2: Allowable Stress

The objectives of the second lab were to test the allowable shear stress in a simple connection and to analyze normal strain in a multi-component cable. In the allowable stress experiment, students used a simple double lap connection (provided in the lab kits and shown in Figure 1) made of balsa wood to measure allowable shear stress. Students added an adhesive (such as double sided tape) to the Part B illustrated in Figure 1, and then suspended increasing weight to get to failure. In this lab, as well as many other labs, students were required to fashion a hanger system and determine a means to accurately determine force (by weight). The example was given to use a known volume of water which has a predictable density to determine the weight. Students were also required to photograph and describe their individual setups as well as analyze the errors that might be introduced with their individual systems.

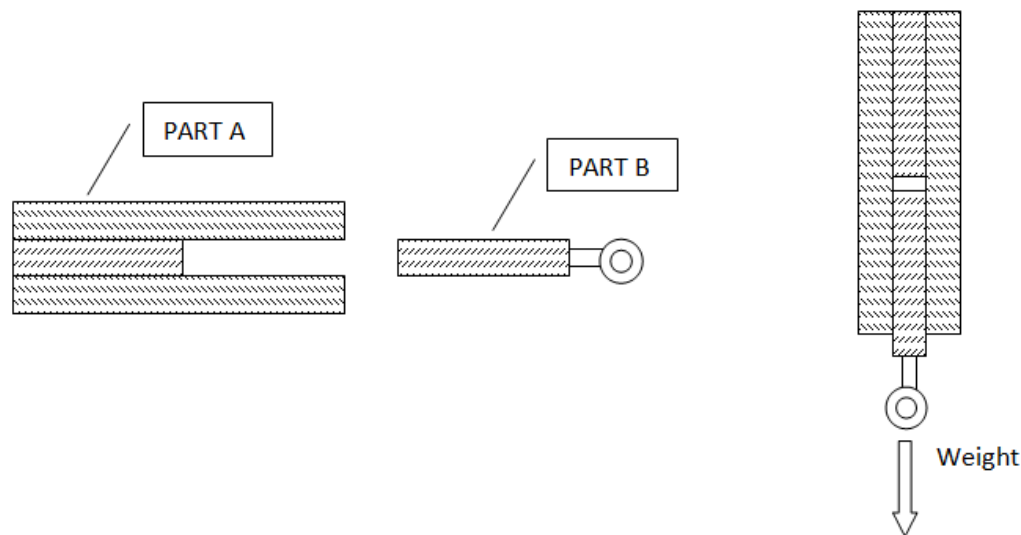


Figure 1: Setup for allowable shear stress experiment

The allowable stress lab also included an exercise adapted from “*Real Life Examples in Mechanics of Solids*.”⁵ Students were given a composite electrical cord and asked to dissect it. Students then performed calculations on differential strain carried by the various materials within the composite.

Lab 3: Tension

In this lab students performed a tensile test on copper wire at home and plotted a stress-strain curve. Students also performed a simulated tensile test on a steel bar. In the first part of the lab

students performed a simple tensile test on a thin copper wire (Figure 2). As in the allowable stress lab, students were required to devise their own system of weights to test the tensile strength of the thin copper wire provided in their testing kits. They marked the gauge length of the wire and used a caliper to measure the strain. Students created a plot of the stress-strain curve for their measurements.

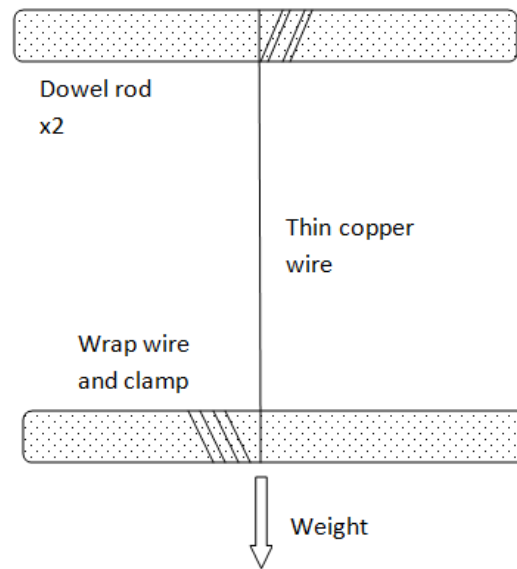


Figure 2: Setup for copper wire tension experiment

For the second part of the lab students performed a simulation and analyzed the results of a tensile test on a steel bar using a web-based java applet no longer available. They also watched a video of a tensile test being performed in a full-scale laboratory experiment.

Lab 4: Creep

In Lab 4 students observed and collected data on creep. Students were provided with an 8-inch length of 60/40 tin-lead solder, the type typically used for stained glass applications. Students hung a full gallon jug of water from the end of the solder and measured the increase in length over time. This lab was primarily an exercise in observation – with students taking measurements and creating a graph over time. Students were asked to observe the changes in appearance of the sample, and to hypothesize on the effects of temperature on their experimental conditions.

Lab 5: Shear Modulus / Thermal Expansion

In this lab students determined the shear modulus of a craft foam sample and explored the effects of temperature on expansion and creep. The setup for the shear modulus experiment included a piece of high density poly-craft foam sandwiched between two pieces of basswood (setup provided in the lab kit and shown in Figure 3). Students used their weight system to create increasing force on the free-floating smaller piece of wood and then measure the angle created

within the foam due to the applied shear force. Students calculated the shear modulus, G , for the foam and compared their value with those obtained by other students in the class.

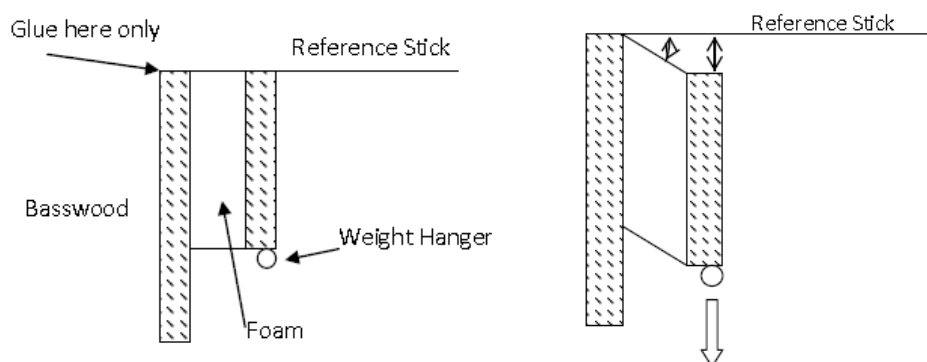


Figure 3: Setup for shear modulus experiment

The second portion of the lab considered thermal expansion. It included the measurements of length, width and height of a supplied block of paraffin wax at room temperature and after being placed in a freezer for 24 hours. Paraffin wax was chosen due to its high thermal expansion coefficient and the fact that it is a solid at room temperature. Students were able to compare their calculated coefficients with published values for paraffin wax.

A second thermal experiment was also conducted where students suspended a weight on a rubber band and then heat the rubber band with a hair dryer. Though no calculations were performed in this demonstration, students were asked to reflect on their hypothesis from the previous experiment on creep and consider the design implications with different materials that undergo temperature fluctuations.

Lab 6: Stress Concentration

In Lab 6 students explored the effects of shape on the concentration of stresses. This lab was largely a demonstration and observation experiment. Students were given two templates and asked to use those templates to cut out standard shapes (dog-bone and square-edge) of aluminum foil. Using the same hanging setup as the copper wire tension experiment, students suspended weights until the foil ripped and then compare the maximum stress for each shape. Students were then challenged to test shapes of their own design and compare them with the two extremes provided by the templates.

Lab 7: Angle of Twist

In this lab students explored the effects of torsion on angle of twist. This was the most complex experimental setup contained in the lab kit. The torsion experiment shown in Figure 4 included two sliding glass door rollers (with ball bearings) held to a wood board by U-bolts and aligned to pass a dowel or quarter-inch steel bar between them. In the middle of the two bearings, a three-inch pulley sheave was also threaded through the dowel and affixed with a set screw. This allowed the dowel to turn with the pulley, but rotate freely within the bearings. The other free end of the dowel was then fixed in a block of wood to prevent rotation. Students were provided

with the two bearings, u-bolts, pulley sheave with attached set-screw. Students were then responsible for constructing the torsion setup and performing the experiment. In the experiment, students hung weights from the pulley, and then measured the angle of twist. The data was plotted and the shear modulus, G , was calculated. Students were asked to repeat the experiment with a different material or the same material at a different length.

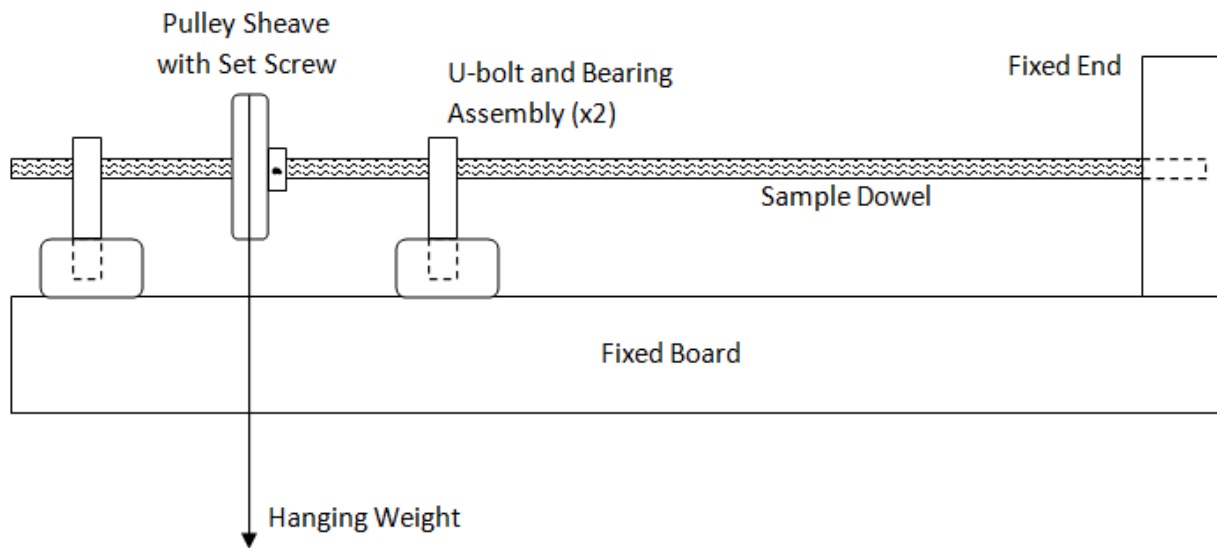


Figure 4: Setup of angle of twist experiment

Lab 8: Beam Bending

Students predicted and observed beam bending in Lab 8. They were asked to choose three materials from home and fix them at one end to create a cantilevered beam. Students calculated the moment of inertia for each beam and obtained the Young's modulus from the internet. Students were asked to predict the displacement of the free end of the beam based on applied force. Students hung weight at the unsupported end of their "beams" and measured the deflection. Students compared their measured results with their predicted results.

Lab 9: Beam Deflection

The objective of this lab was to predict and observe the deflection of a simply supported beam. Similarly to the beam bending experiment, students were asked to collect three materials from home to test. Students created a simply supported beam by placing the beam between two supports without fixing them as shown in Figure 5. Students then used theory to predict deflection based on known or estimated properties of the materials. Weights were then hung from the center of each beam and the deflection measured and compared with the theoretical results.

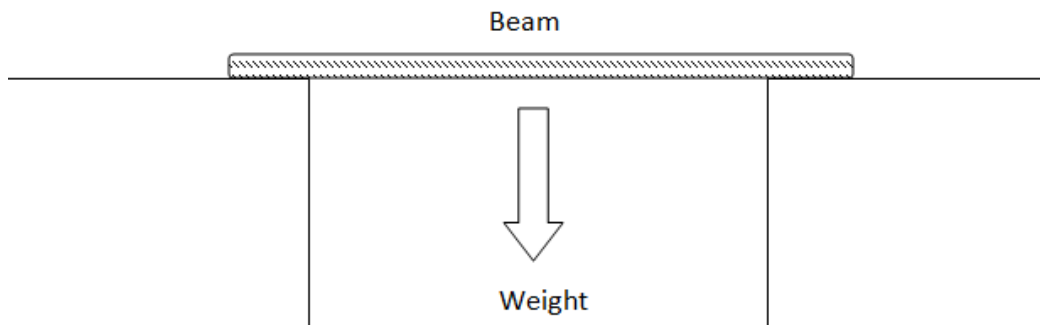


Figure 5: Simply supported beam for deflection experiment

Lab 10: Buckling and/or Pressure Vessels

The final lab's objectives were to perform a thought experiment, apply creative thinking skills, and apply knowledge of materials science applications. In this experiment, students were asked to design an experiment with commonly available materials to test a principle of either buckling or stress/strain transformation. Students designed experiments, created a drawing of the hypothetical setup, and then wrote out the experimental procedures and explained the theory it was designed to test. This lab served as a culmination of the lab course and a chance to apply skills learned to new and creative circumstances.

Observations

The mechanics of materials course with the home-based labs was offered the first time in the fall semester of 2011 to a distance education class. The class consisted of 13 students. Each student was given a lab kit containing most of the necessary materials needed to perform the experiments. They would need to acquire any other materials necessary to complete the labs such as a caliper and a scale. The following section outlines some comments from these students regarding the labs as well as some thoughts from the instructor of the lab component of the course.

For the most part, feedback from the students regarding the labs was positive. Most students stated the labs were a success in that they helped reinforce the concepts taught in the lecture. One student stated, "...at the start of class I was a little concerned how well it would work out doing the labs at home. In reality, I found the labs to be doable, interesting, and a positive learning experience." Another positive outcome students reiterated was that designing and building the experiments was enjoyable. The word "fun" was used by several students in assessing the lab experience.

Of course, there were negative comments from the students as well. Many students suggested not having accurate weights made the labs difficult and frustrating. The instructor suggested using water as a source of loading in the experiments as the density of water is known and the volume can easily be measured. However, students believed this did not give good results. One student that invested in an inexpensive weight set said, "Using water for weight is annoying and really limits you on where you can do the labs. Investing in an inexpensive weight really makes the labs more enjoyable." Another theme in negative comments was about the added cost of the

lab equipment. Requiring the purchase of some of the equipment like a scale or caliper was seen as a bit excessive to several students. One student stated, “[For] lab courses on the campus, any student expects that the materials are already made available...but paying for a lab class and paying for the materials just took too much [from] the students.”

The instructor of the course felt that the labs were overall a success. Students were able to complete the assignments, seemed to enjoy the assignments, and did an especially good job of extending their experimental observations to new applications. Development of the labs created several challenges, including selecting materials that were low cost, but exhibited the desired behavior. It proved especially difficult to create a torsion setup that could be replicated at home with minimal friction interference. However, the resulting setup worked very well and student results were positive. Finding a balance between the included components of the lab kit and the cost of the kit will be an ongoing challenge.

Conclusions

The purpose of this project was to create a set of at-home laboratory experiments to compliment a mechanics of materials course taught through distance education (asynchronous online and synchronous audiographic courses). The challenges of developing the laboratory kits included selection of materials, inclusion of robust content, and minimizing the student cost.

The outcome of the initial offering of the lab course was successful, with students gaining proficiency with measurement, calculations, and applications of the theoretical lecture content. Student feedback was positive, with many students both enjoying the labs and expressing positive learning from them. Some challenges remain, such as accurate home weight systems and maintaining a low out-of-pocket cost.

Future work on this project includes additional assessment to quantify student learning gains over the course of the semester, and work to address the ongoing challenges described above. Also, the labs must be implemented to the online delivery of the course. The online mechanics of materials course is currently being developed and the first offering, including these labs, will occur in an upcoming semester.

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Comparison of On-Campus and Distance Learning Preferences in a Junior-level Materials Science Course

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Abstract

Students taking courses in face-to-face and asynchronous formats face potentially different barriers to learning in engineering courses. During the Fall 2011 semester, students enrolled in ME 301: Materials Science were surveyed regarding which teaching methods they found the most beneficial to their learning experience and how confident they were in their mastery of the course material. Over 90% of the students responded to the survey. Approximately 20% of the respondents were distance students. Both groups reported the largest positive effect on their learning from viewing lectures compared to participating in class discussions or in-class group activities. The difference in average response from the two groups was also largest for questions related to the benefits of the lectures. When asked about their confidence in discussing course material with the instructor, distance students tended to respond significantly higher, while the face-to-face students tended to report being more confident than distance students in discussing course concepts with their peers. Distance students tended to have more positive associations with recorded lectures than with other teaching formats but reported being somewhat less prepared for exams. Grades for distance students were lower overall and in each assessment category (exam, homework, etc.). Data from a subsequent survey of distance students administered during the Spring 2012 semester will provide insights into the motivations and backgrounds of distance students in the program.

Introduction

The number of courses being offered via some manner of distance delivery continues to increase. In 2009, Parsad and Lewis reported that two-thirds of 2- and 4-year post-secondary institutions offered some form of online learning¹. Since then, the potential of massive online open courses (MOOCs) to connect with students around the globe has attracted interest from many institutions of higher education. Many schools offer fully-online degree programs in various disciplines^{2,3}. Despite the potential advantages of distance education in terms of physical resources for the institution and flexibility for both students and instructors, to the authors' knowledge the University of North Dakota (UND) remains the only university in the world to offer ABET-accredited undergraduate engineering degrees at a distance.

The UND Distance Engineering Degree Program (DEDP) includes a combination of asynchronous courses and compressed, on-campus laboratory experiences. Many of the students in the program are working professionals, taking one to two courses each term in addition to working full-time and often balancing family commitments. Time-to-degree for these students can exceed 10 years depending on the number of credits with which they enter the program and

the credit load they can carry with their other responsibilities. Dunderstadt observed that the demographics of the student body are changing, regardless of the delivery mode⁴. Based on anecdotal experience with the DEDP at UND, the expansion of distance education is playing a large role in these demographic shifts.

Kinney *et al.* reported the results of surveys of faculty and students involved with distance courses (primarily at the graduate level) and found that faculty and student perceptions diverged in several areas⁵. For example, students identified recorded online videos as the most effective online instructional tool while faculty identified online course materials and ranked recorded videos fifth. Students identified social networking and text/chat as the least effective instructional tools while faculty selected virtual labs and virtual worlds⁵.

Other researchers have focused on comparisons of the quality of the education achieved in online courses versus more traditional classes. Results have both supported and condemned distance learning. Researcher conclusions have ranged from linking online education to the death of learning⁶, to noting that student performance on various assessment measures shows no appreciable difference from their on-campus counterparts in some courses but did differ in others⁷.

The current work investigates the background and motivations of distance engineering students in a junior-level materials science course. It also investigates the results of a survey of both distance and on-campus students in the course regarding which teaching methods they found most helpful to their learning. Finally, a comparison of distance and on-campus student performance on several assessment types are presented and discussed.

Methods

In December 2011, a survey was distributed electronically to all students in ME 301: Materials Science. This included two on-campus sections (63 students) and one distance section (20 students). Table 1 shows the questions included in the survey.

Table 1: Questions in electronic survey regarding teaching methods

1. Are you on-campus or DEDP?
2. Which of the following class activities helped you learn the course materials? Selected all that apply: <ul style="list-style-type: none"> • Lectures • Class discussions and in-class question-and-answer sessions • Synthesis activities in class • Exams • Synthesis questions on exams
For each item in (2), the following questions were asked:
3. What did you like best about X (where X was lectures, class discussions, etc.)?
4. What did you not like about X?
5. How well did X prepare you for the exams?
6. After completing X, how confident were you in your abilities?
7. After completing X, how confident are you in discussing with your peers?

8. After completing X, how confident are you in discussing with your instructor?
Two final questions and demographic information were then asked:
9. After taking this course, how confident are you in your overall engineering abilities?
10. Overall, to what extent do you feel confident in your ability to succeed in engineering?

Student grades for ME 301 for Fall 2012 were also analyzed. Relative performance of distance students and on-campus students was assessed.

In addition, during the Spring 2012 semester, a second survey was distributed to DEDP students in the ME program (not just ME 301). Thirty-one students responded (approximately 20% of the distance students enrolled that term). Students were asked to report the type of previous institution(s) they had previously attended as well as their motivations for 1) obtaining an engineering degree and 2) pursuing their degree at a distance. They were also asked why they chose UND, why they left their previous institutions, how much time had elapsed between enrolling at their previous institution and enrolling at UND and their current employer category.

Results and Discussion

Survey results from on-campus and distance students from the ME 301 survey were compared to determine what differences, if any, existed between the perceived effectiveness of different teaching techniques. The techniques investigated were the lectures (live lectures for on-campus or recorded lectures for the distance students), in-class discussions (distance students would not be able to participate due to the asynchronous nature of the course but could observe), or synthesis exercises (this is the name given to open-ended problem sets completed in class that required integration – synthesis – of multiple concepts from throughout the semester). Student responses to each question were assigned a numerical weight from 0 to 4. The average response from each group was then calculated and compared. An average response greater than two thus indicates a generally positive effect and an average response less than two indicates a generally negative effect.

Responses to questions 5-7 (see Table 1) were uniformly positive among both groups of students (average response >2). Both on-campus and distance students reported that the pedagogies used in the course made them feel better prepared for the exams. The techniques also increased the students' overall confidence and the students' comfort in discussing the material with their peers. However, on-campus students' responses to question 8, regarding their confidence in discussing the material with their instructor, were uniformly negative (average response <2). Distance students reported a positive effect from lectures, a neutral effect from class discussions and a negative effect from synthesis exercises. Tables 2a and 2b summarize these results for DEDP and on-campus students, respectively.

Table 2a Average student responses from DEDP students regarding positive impact of lectures, class discussions, and synthesis exercises

<u>Pedagogy</u>	<u>Influence on</u>	<u>Avg Response</u>
Lecture	Exam Preparation	2.38
	Overall Confidence	2.44
	Confidence in Peer Discussion	2.40

	Confidence in Instructor Discussion	2.33
In-Class Discussions	Exam Preparation	2.07
	Overall Confidence	2.16
	Confidence in Peer Discussion	2.11
	Confidence in Instructor Discussion	2.00
Synthesis Exercises	Exam Preparation	2.04
	Overall Confidence	2.04
	Confidence in Peer Discussion	2.09
	Confidence in Instructor Discussion	1.93

Table 2b Average student responses from on-campus students regarding positive impact of lectures, class discussions, and synthesis exercises

<u>Pedagogy</u>	<u>Influence on</u>	<u>Avg Response</u>
Lecture	Exam Preparation	2.48
	Overall Confidence	2.27
	Confidence in Peer Discussion	2.25
	Confidence in Instructor Discussion	1.83
In-Class Discussions	Exam Preparation	2.13
	Overall Confidence	2.16
	Confidence in Peer Discussion	2.22
	Confidence in Instructor Discussion	1.74
Synthesis Exercises	Exam Preparation	2.10
	Overall Confidence	2.12
	Confidence in Peer Discussion	2.18
	Confidence in Instructor Discussion	1.83

The percent difference between the mean responses was calculated as:

$$\frac{(Mean\ DEDP\ Response) - (Mean\ On-Campus\ Response)}{Mean\ On-Campus\ Response} \quad Eq. 1$$

Figures 1-3 show a comparison of the relative importance assigned by each group to the techniques. For most questions, the mean response for DEDP students was within 10% of the mean response for on-campus students. In all three cases, the question that generated the largest difference in response between on-campus and distance students was, "...how confident are you discussing with your instructor." Because no pre-tests were performed, it is not possible to know how much of this difference is directly related to the teaching methods and how much is related to a differing level of maturity between on-campus and DEDP students.

On-campus and DEDP students reported approximately the same overall confidence level in their engineering abilities after completing the course (2.19 – on-campus, 2.20 – DEDP). Both groups had a strongly positive response regarding their ability to succeed in engineering (2.62 – on-campus, 2.80 – DEDP).

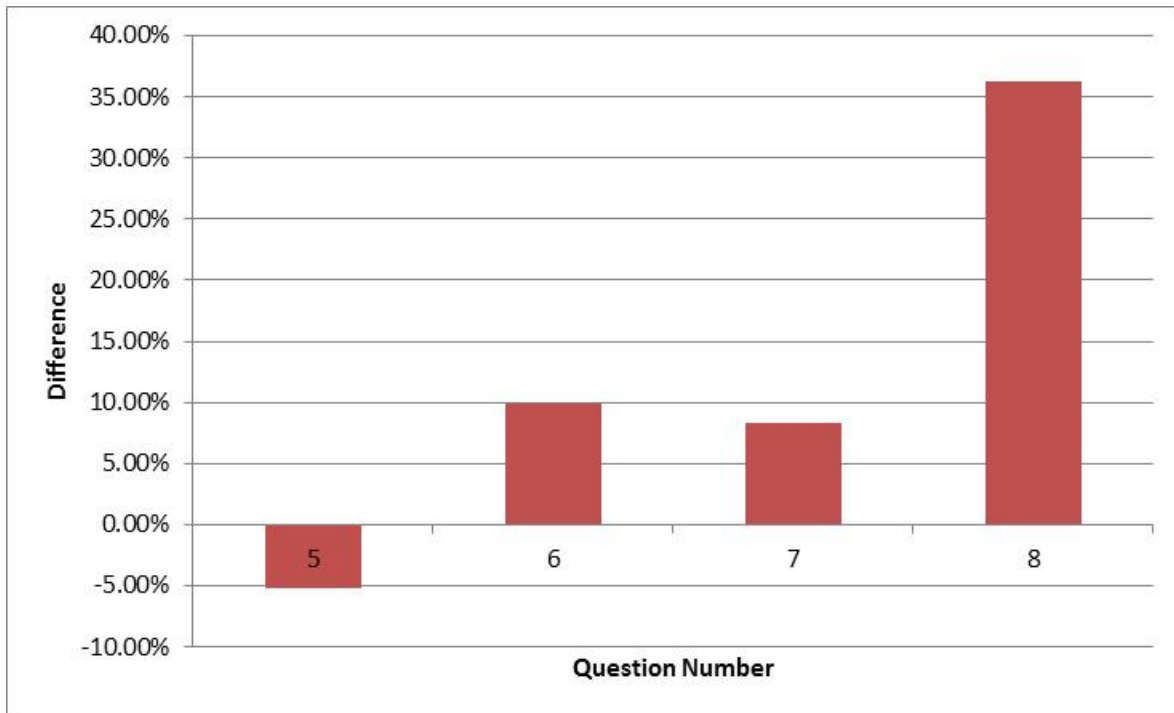


Figure 1: Comparison of relative perceived effectiveness of lecture on learning for DEDP versus on-campus students

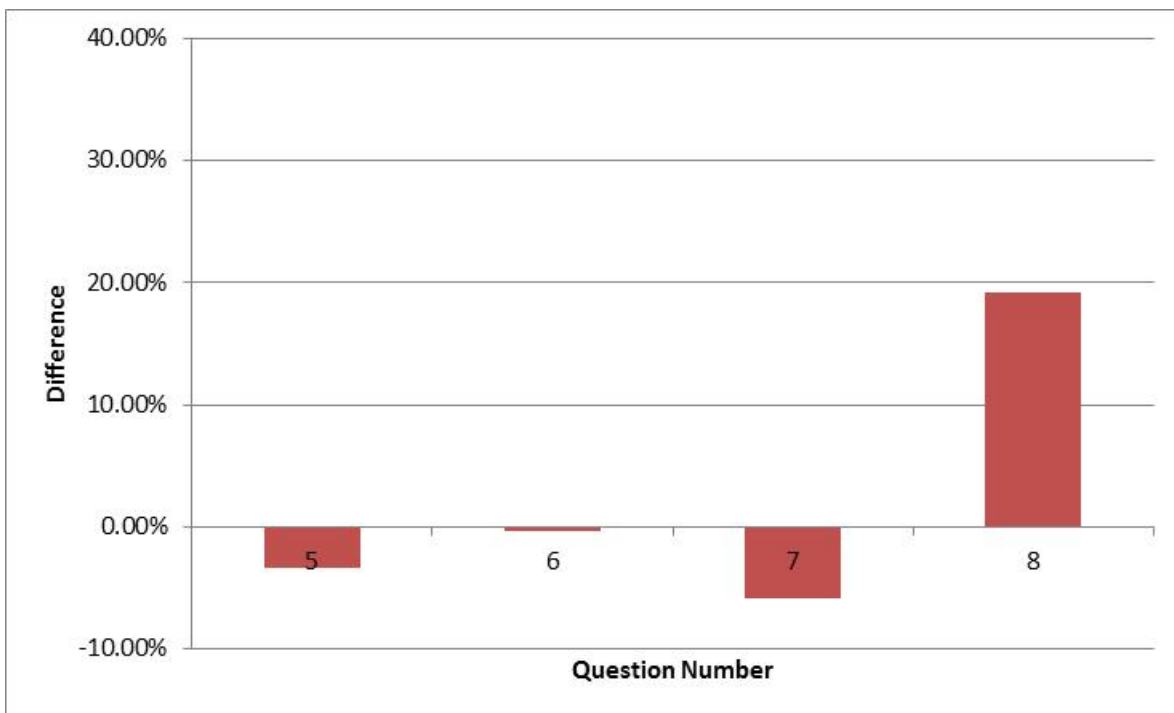


Figure 2: Comparison of relative perceived effectiveness of class discussions on learning for DEDP versus on-campus students

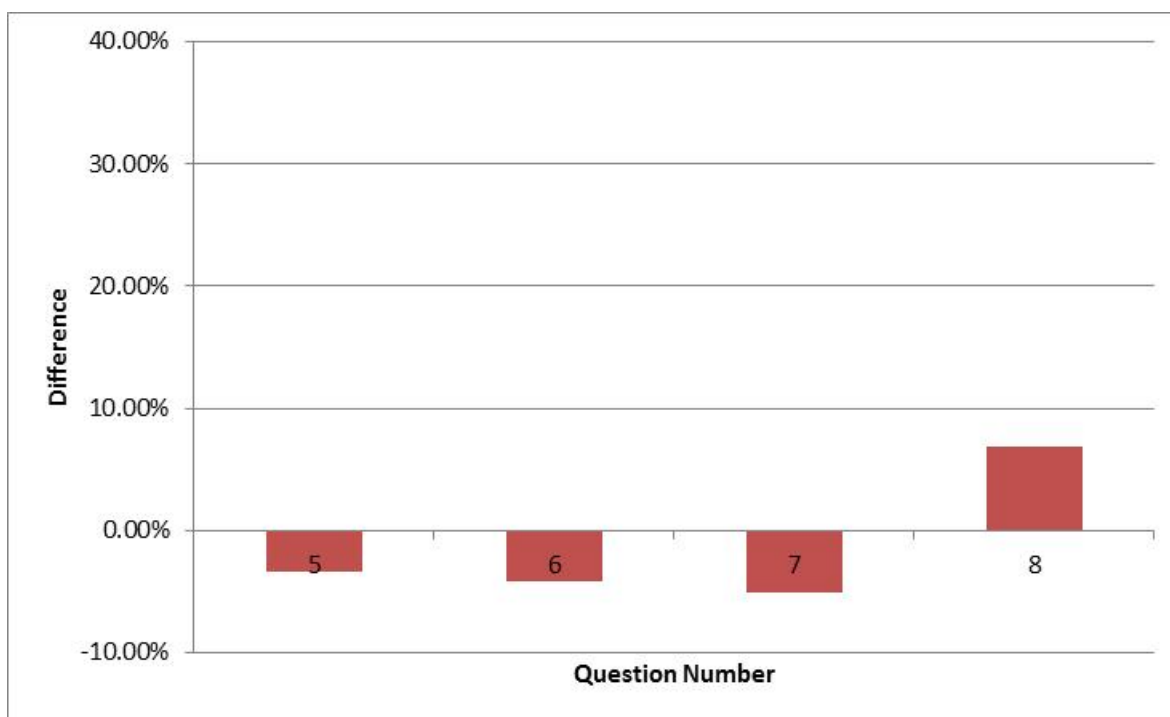


Figure 3: Comparison of relative perceived effectiveness of synthesis exercises on learning for DEDP versus on-campus students

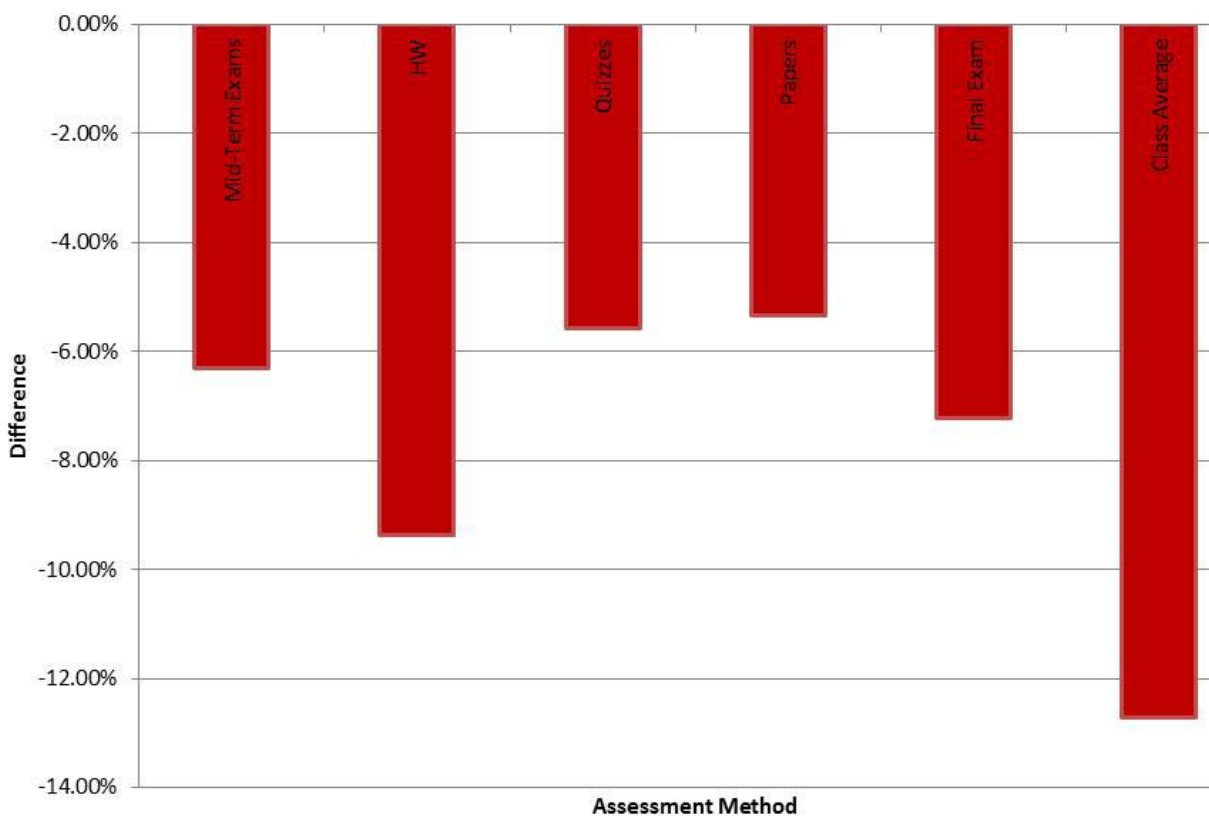


Figure 4: Comparison of student grades (DEDP vs on-campus) sorted by assessment method

Figures 1-3 represent indirect proof of the learning that is occurring in each group of students during the semester because they rely on the students' self-reported performance rather than direct assessment measures. To provide some more objective assessment data, the average grades of the on-campus and DEDP students were compared. Both the final course grade and the grades on individual course components (e.g. homework, mid-term exams, etc.) were compared. The results are displayed in Figure 4. Average grades for DEDP students in all categories are lower than for their on-campus counterparts.

Demographic results from the ME 301 survey indicated that all DEDP students were in the '24 years old or older category' (no further breakdown of older age groups was provided). In contrast, only 12.7% of the on-campus students fell into this category. One on-campus student did not respond, but 85.7% of the on-campus students indicated they were 20-23 years of age (ME 301 is typically taken during the fall of the junior year).

Ninety percent of the distance engineering students responding to the Spring 2012 survey had attended a post-secondary institution prior to enrolling in the distance program. Figure 5 shows the breakdown of the categories of previous institutions attended by the students.

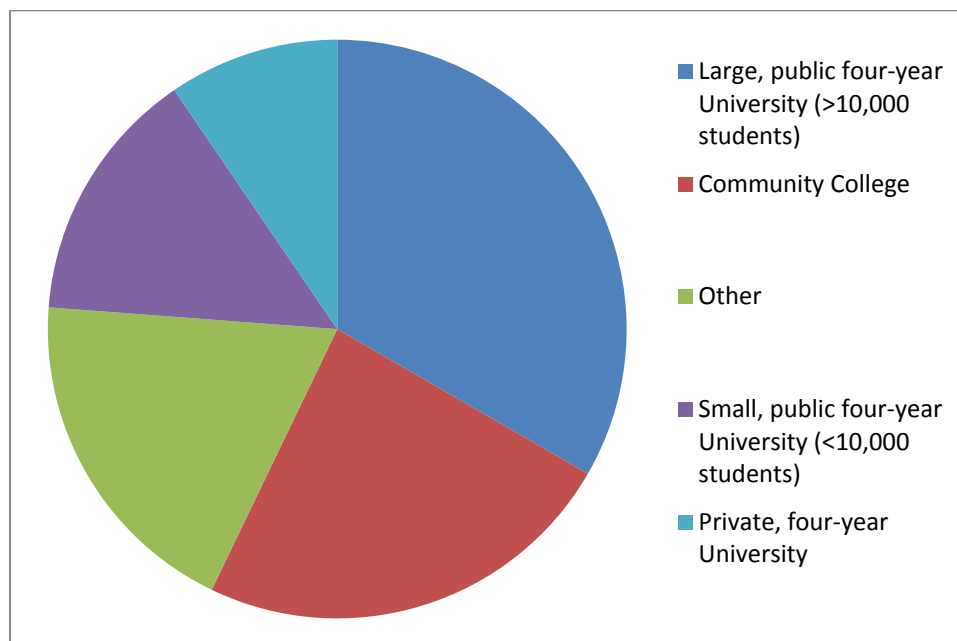


Figure 5: Previous institutions (by type) attended by UND distance engineering students

Most students indicated that they initially left post-secondary education due to family or financial reasons – only five percent indicated academic reasons. Half of the returning students were enrolled in an engineering or related discipline before entering the distance program at UND. The survey respondents universally indicated that the program's flexibility, both in location and time, was a major factor in their decision to enroll at UND. Figure 6 shows the motivations of these students for pursuing an engineering degree. Students responding 'Other' typically cited multiple categories of responses (i.e. Change careers and Obtain a promotion) rather than a completely new motivation.

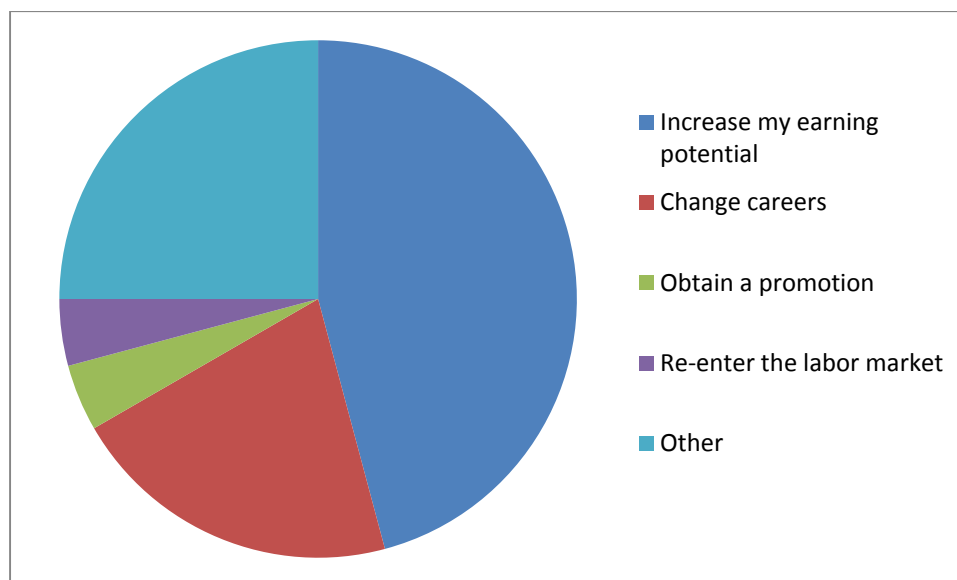


Figure 6: Motivations for UND distance engineering students

Conclusions

Both on-campus and distance learners identified traditional lecture pedagogy as contributing more to their confidence about material mastery than in-class discussions or more open-ended, synthesis exercises. No further data was gathered to explain this preference. The authors posit that it is possible that this preference is related to the fact that the lecture setting is probably the most familiar to students based on their previous experiences.

DEDP students report increased confidence in material mastery arising from the lectures compared to their on-campus counterparts. In contrast, on-campus students report increased confidence in material mastery arising from both in-class discussions and synthesis exercises (completed as groups during class). It is perhaps not surprising that the distance students report less impact from these activities since they are not able to directly participate with their peers due to the asynchronous format. Interestingly, distance learners report higher confidence in discussing course material with the instructor than on-campus students regardless of the pedagogy. This may be related to the fact that the majority of distance learners are both older and have more professional experience than the typical on-campus student.

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Effectiveness of Self-Paced Graphics/Visualization Tutorial for Engineering Students (work-in-progress)

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Introduction

Visualization is a critical component of the engineering design process. It also plays a vital role in engineering education from the very early stages. To be able to break down and analyze most engineering problems, one has to be able to visualize the context of the problem.

At the University of Wisconsin-Platteville (UW-P), visualization for engineering problem solving is covered in an introductory course GE 1320 Engineering Computer Graphics. This course has been required of all engineering freshmen except the Electrical and Software Engineering majors until recently. Since fall 2009, all Mechanical Engineering (ME) majors are required to take GE 2030 Engineering Modeling and Design, a new sophomore level solid modeling course instead of GE 1320 at the freshman level. This decision was made in order to address industry demands for ME graduates to have expanded exposure to solid modeling. The other side to this however, is that many intended ME majors will not be eligible to take this course which requires a co-requisite of Calculus I during their first year. A significant percentage of our incoming students begin at the Pre-Calculus level, not to mention those at the remedial level. For such students, there will be a substantial time lapse between introductory engineering courses and the modeling course.

First-hand understanding of student needs and preparedness supported by data gathered over a period of more than four years suggest that a large segment of our students who intend to major in engineering programs come with no prior exposure to engineering graphics and limited visualization skills. Others who took courses in Project Lead the Way or a Tech-Ed program in high school have some basic knowledge of reading and interpreting drawings. With the intent of closing the achievement gap of these students and also to provide an opportunity for review for others, a set of materials was developed by the authors. These materials include a set of interactive tutorials on basic topics covered in GE 1320 Engineering Computer Graphics. Students could use the material, made available on-line, at their own pace and level to cover deficiencies. This has been made available to students in all four sections of GE 1320 for the first time in the spring 2012 semester. A comparison of student performances before the tutorial was made available to all and after, will be discussed in this paper.

Background/Prior experience of students

For this preliminary study we looked at students enrolled in GE 1320 Engineering Computer Graphics course at the University over a period of two semesters beginning fall 2011. Four sections of this course are offered each semester. All students majoring in Civil, Environmental, and Industrial engineering take this course as a core requirement for their major. Out of a total

number (297) of students in a control group 58% had some exposure to a structured graphics course before coming to college with 35% reporting that they had used AutoCAD while 19% used a variety of other CAD packages.

The concern is that even though a significant percentage of incoming students had some prior CAD experience they lack sufficient visualization skills. The GE 1320 course progresses at a fast pace through topics as discussed later. Many students struggle at the beginning while they are getting used to the idea of visualization. Therefore, by providing extra help in the form of an on-line self-paced tutorial students are expected to do better and eventually benefit.

Topics covered in GE 1320 Engineering Computer Graphics

Following is the official course description from the University catalog:

Problems relative to points, lines and planes in space; Cartesian coordinates; projection-plane theory; orthographic pictorials; dimensioning; auxiliary views; sections; extensive use of computer-aided design (AutoCAD and solid modeling) including 2D and 3D drawing, editing and enhancing; emphasis on development of the ability to communicate graphically; special emphasis on engineering and computer graphics applications. Two 2-hour classes per week. (Fall, spring). Pre/Co-requisites for the course GENENG 1000 Engineering Success Skills and MATH 2530 Trigonometry and Analytic Geometry.

Visualization tutorial made available to students

A graphics/visualization tutorial developed earlier by the authors was made available to students in the control group consisting of four sections of GE 1320 during the spring 2012 semester. In addition to posting the material on-line via D2L (Desire to Learn) for easy access, students were reminded periodically to take advantage of the resource and go over the practice problems and tests.

Tutorial and practice problems provided in the package include (a) Construction and isometric sketching of buildings, (b) Surface and edge identification, (c) Rotation of objects, (d) Reflection and symmetry, and (e) Orthographic projections. Each unit is introduced with a short description of the concept followed by worked out examples which students can follow interactively. A number of problems at various levels of complexity are also included for practice.

Methodology

For this study we used data obtained from two consecutive semesters (fall 2011 and spring 2012). As mentioned earlier four sections of the course were offered both semesters. Students enrolled in fall 2011 did not have access to the tutorial while spring 2012 students in all sections were given access. In addition they were encouraged to use the material with frequent reminders in class.

For comparison purposes two exams were selected from each semester. The exams were selected on the basis of concepts they covered and the timeline. Average student performance data were extracted and compared between the two semesters. Also, four sets of homework were selected

for comparison. Individual exams and problem sets as well as the overall average were compared.

The final exam scores and written portion of the end of semester final exam was used as well. The written portion of the final is given during the finals week typically a whole week after the students complete their CAD portion of the final exam in the course. In this multiple choice one hour test students are asked to answer questions indicating the best or only answer to questions. The questions cover a wide variety of basic concepts, definitions, practices and symbols. Students are tested on whether they can identify the missing views from a set of proposed views. In addition, they are asked to match a set of orthographic views with the corresponding isometric view from a group of given views. The following are a couple of sample questions from the test:

- i. In orthographic projection, a horizontal surface would appear in front view as: (a) oblique surface (b) inclined surface, (c) true size surface, (d) edge.
- ii. A primary auxiliary view projected from a right side view will show which principal dimension as a true measurement? (a) height, (b) width, (c) length, (d) depth.
- iii. The angles between the principal axes of an isometric (at the point tilted towards you) are how far apart? (a) 30 degrees, (b) 60 degrees, (c) 120 degrees, (d) 150 degrees.

The overall course grades for the two semesters are then compared.

Analysis of results and discussion

As mentioned earlier, two exams and four sets of homework problems were selected from the two semesters in question – fall 2011, when no visualization tutorial was available and spring 2012, when the tutorial was made available.

When comparing individual exam scores it was found that there was some improvement in scores in both exam 1 and exam 2. In fall 2011 the scores were: 79.4% in exam 1 and 71.2% in exam 2 and in the spring 2012 semester the corresponding scores went up to 87% in exam 1 and 77.6% in exam 2. The overall exam scores improved from 75.2% to 82.4%.

When comparing scores in individual homework sets or overall average of homework there was no change observed. Average scores in homework remained the same in both semesters around 86%. No significant change in homework set scores is not a surprise. Students usually work in groups and use help from the tutors available in the labs for long hours during the semester. When approached, instructors also help students complete their homework.

The scores of written portions of the final exam as well as the final course grades were compared. As indicated above, the written portion of the final exam is given during the finals week. Students answer 25 multiple choice questions in an hour. The other portion of the final exam is a two-hour CAD final given during the last week of classes of the semester. When comparing final course grade in individual sections as well the combined average in the course it was found that there was some improvement in the scores between the two semesters in question. In fall 2011 the combined average score was 79.7% (ranging from a low of 74.5% in section 1

to a high of 82% in section 4), and in the spring 2012 semester the corresponding score went up to 81.8% (ranging from a low of 80.4% in section 2 to a high of 82% in section 3).

When comparing scores in the written portion of the final exam among individual sections or all sections combined there was no change observed. Average scores in it remained the same in both semesters around 68%.

In reviewing end of semester student feedback it can be concluded that because the tutorial was meant to be a self-paced exercise, only those students that were motivated took advantage of the opportunity. General comments of appreciation in having a tutorial available for beginners showed up a few times.

Conclusion

Although class averages for exams and homework sets have been presented – this does not tell the whole story. The actual impact of the tutorial is not in numbers but in the case of individual students. There were several students who would have failed the course without this additional help. One student in particular, failed the course in the fall semester and repeated it in the spring. He would come in for office help but was also working on the tutorial on his own. He was a much more confident young man in the spring. He received a B+ at the end of the spring semester. Another student struggled early on in the spring semester and would come in for office help frequently. She became more comfortable with the course material after going through the tutorial on her own. This was a hard-working student and she became really confident toward the end of the semester. She received a B in the course. These are examples of the type of students who usually get frustrated with the course material early on and give up or just sit through the semester earning a failing grade – these are the students who could be saved. As mentioned earlier, this is a work in progress and more data will continue to be gathered. Although the preliminary results demonstrate a positive effect, certainly more work needs to be done.

Inspiring Students to use class room Simulation software to Model Industry Manufacturing Process

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ABSTRACT

This senior level class group project work paper demonstrates how to analyse the existing process, layout, manpower, methods & machines and outside vendor processes. The data is collected for each process from start to completion. Each process data is analysed critically and prepared for simulation modelling. A complex product drawing is selected for analysis for this paper. This product manufacturing process involves saw cut operation, rough turning, finish turning, heat treatment, two stage milling, non-destructive testing, and finishing. The part quality is inspected at each stage of operation. The simulation run is defined as batch run of 36 parts per run. This group project encouraged students to work as a team and they were able to benefit from one another's knowledge and expertise. The faculty involvement for this project is very minimal to none. This group project study encouraged students to boldly approach the industrial problem and reinforced their learning skills on a newly learned software program- Arena Simulation Modelling. The student group was able to critically think through the whole project, developed the working simulation model and made recommendations based on "what-if" scenario analysis simulation run.

Keywords: Process, Modeling, Machines, Prediction Modeling

INTRODUCTION

The manufacturing process for the selected product drawing is very complex and involves many stages of processes. The part goes through the following processes: saw cut operation, rough turning, finish turning, heat treatment, two stage milling, non-destructive testing, and finishing. The process quality is inspected at each stage of operation. The above processes are identified for the simulation study. The part drawings selected for the study are shown in Figure 1 and 2.

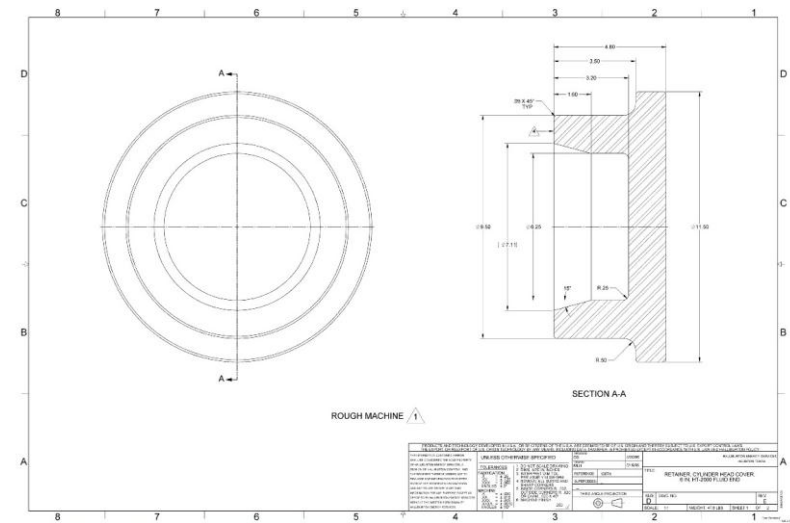


Figure 1: Product Model (Rough Finish)

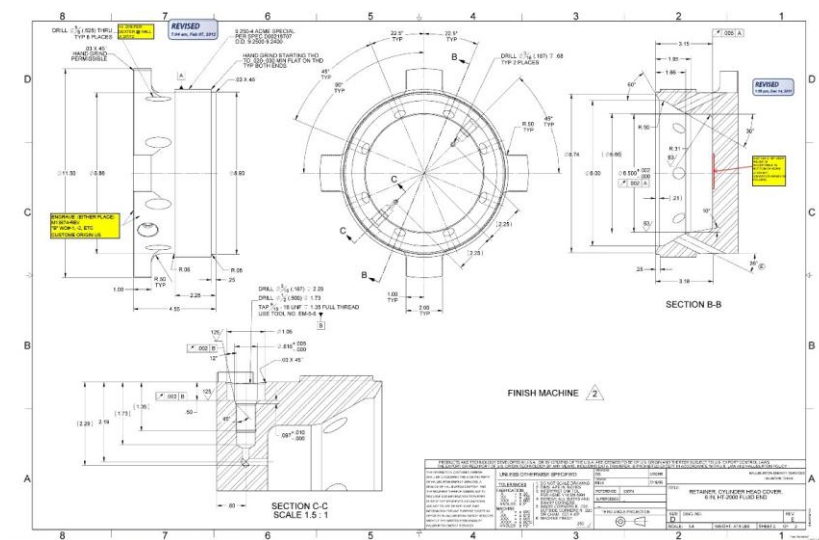


Figure 2: Product Model (Final Finish)

The plant personnel have no idea which process would fail causing the delay in shipment, thus hurting the company's bottom line. By accurately modeling the existing processes, the expected throughput can be predicted based on the process data. This group project paper intends to study the existing production process data, model the existing process in ARENA software and make recommendations to improve the product process throughput.

LITERATURE REVIEW

There are plenty of journal articles and conference proceedings available to predict the machining process throughput. There has been much research work done by subject matter experts on discrete event simulation modeling and techniques. However, not enough research available to predict the product process throughput based on the academic students team work solving a problem using the class room taught simulation program for a group project. Pandian and Ali (2011) ¹ modeled Body- In-White build shop data to simulate the automotive assembly processes using ARENA simulation software. Based on the existing modeling simulation findings, they recommended improving automotive assembly plant throughput by feeding back the actual values of the MTTR/MTBF data in to simulation modeling. There are many approaches used for validation and verification of the simulation model. Various validation techniques such as conceptual model validity, model verification, operational validity and data validity and minimum recommended procedure are discussed by Sargent (2004) ². For specific application, model accreditation standard (DoDI 5000.61) is available from Department of Defense (DoD). Jack Hu and Stecke (2009) ³ offered parallel and hybrid combinations, and their trade-offs improved productivity and dimensional quality compared to traditional assembly systems for automotive bodies that have been designed using serial configurations. Guidelines are developed to aid in the selection of a system configuration that is appropriate for total system performance.

This study is very unique in nature and builds student confidence and reinforces students to approach problems based on the class room knowledge. The ARENA modeling software V 13.90 (2010) ⁴ is used to analyze and model the product process.

PRODUCT – PROCESS FLOW

The product drawing shown in Figures 1 &2 requires the following stages of operation as shown in Figure 3. The various processes require quality inspection at the end of the operation (not shown in the figure). The process times are evaluated from the operator work order time cards for each process. The heat treatment and non-destructive testing lead times are also modeled in the program. A typical work order is shown in Figure 4. Only the first page is shown in Figure 4 due to propriety information. The actual part is shown in Figure 5.

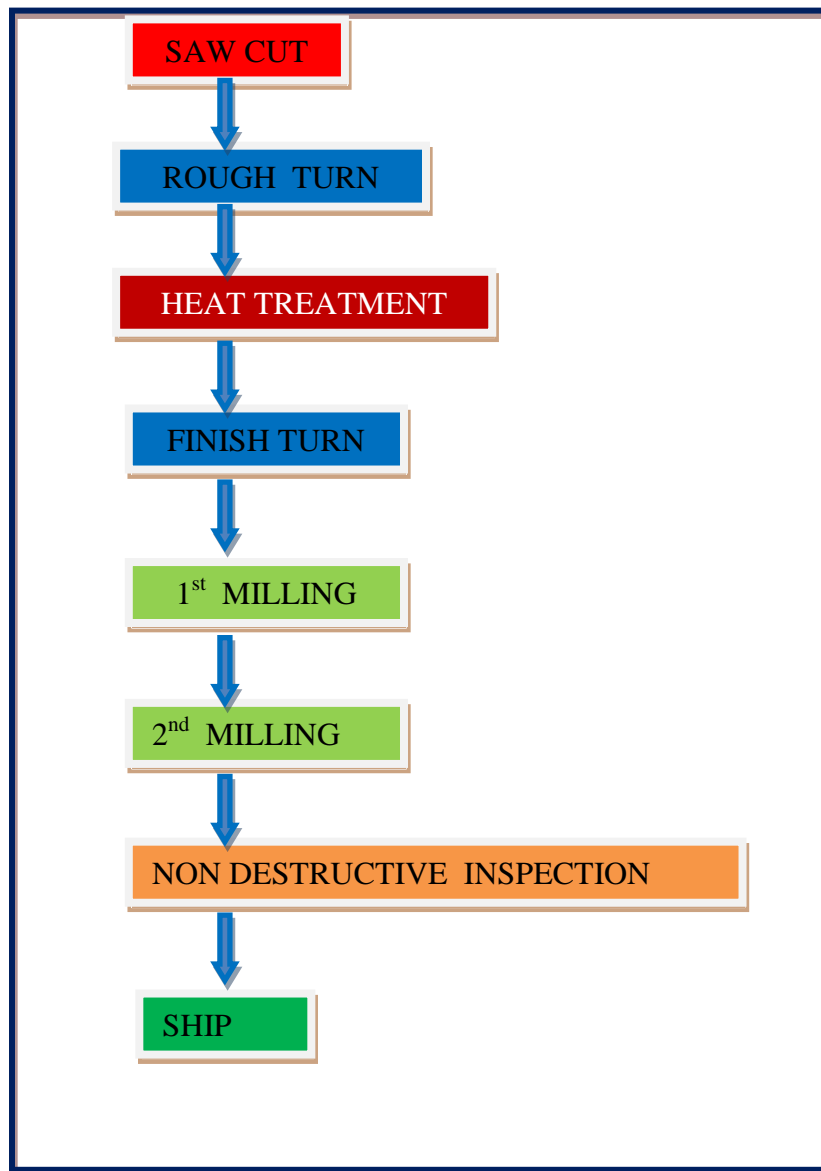


Figure 3: Process flow diagram

OEM Fabricators, Inc. Work Order Traveller **COPY** 3/30/2012 9:43 AM
WORK ORDER ID: 382449/1 Page 1

Order ID: 229049

Ship Via: [REDACTED]
Cust PO#: 4508846515

Part ID: 13574 RETAINER, CYL HEAD COVER 6" REV: G

Work Order ID	Part ID	Release	WantDate	Start Date	Finish Date	Qty	Drawing ID/Rev
382449/1	13574	3/11/2012	4/5/2012	3/11/2012	4/11/2012	36.00	334.26009/E
RETAINER, CYL HEAD COVER 6"							

Shop Resources	Seq#	End Qty	Start Qty	Setup Hrs	Run Hrs	Operator
SAW	10	36	36	0.20	7.20	First Piece Insp
SAW TO 5.00"						
Part ID/Sub ID Piece# Date Req'd Unit Of Measure Qty Req. Qty Due HR1200 10 2/22/2012 IN 189 3 ROUND 12" 4140 ANN Traceability: N1701 (1,170,50) Sub ID 1 20 1 1 SAMPLE PIECE FOR DESTRUCTION TEST AT HEAT TREAT						
LATHE1A	20	36	36	1.00	32.40	First Piece Insp
ROUGH MACHINE PER PG 2						
PUT SAMPLE PIECE FOR DESTRUCTION TESTING WITH PARTS BEFORE GOING TO HEAT TREAT						
LEG CONSTRAINT LC	22	36	36	0.00	0.04	First Piece Insp
INSPECT	25	36	36	0.00	0.00	First Piece Insp
SEND SAMPLE PIECE FOR DESTRUCTION TEST						

Figure 4: Work Order

Manufactured Part

- Retainer Cylinder Head Cover
- Batch Size Of 36 Parts
- Part Outsourced For Two Processes
 - Quenching & Tempering
 - Phosphate Finishing
- Process Data Recorded From 11 Production Runs
 - Labor Tickets & Work Orders
 - Inaccurate Data For Certain Processes
 - Scrap Not Properly Recorded



Figure 5: Actual finished part

The production line data is collected, tabulated, and analyzed for ARENA Simulation modeling.

ARENA MODELING

The actual process times are shown in Figure 6. The model is shown in Figure 7 which represents the screen shot of the model developed for the product drawing shown in Figures 1 & 2. The simulation model was built using these actual times. The actual time it takes to process a batch of 36 parts per run takes about 7275 minutes.

Manufacturing Processes

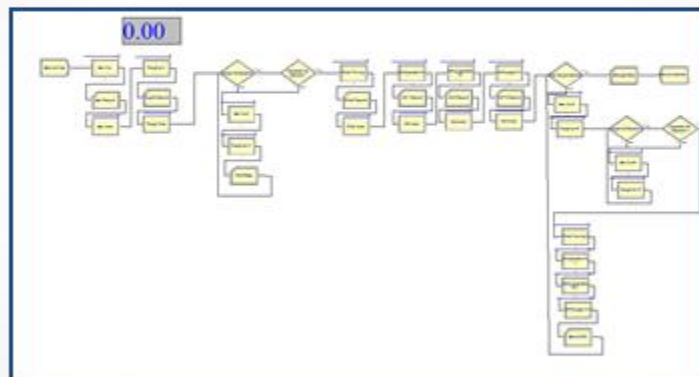
Operation	Seq. #	Total Hours	Total Minutes	Min/Part
Saw	10	177.27	10636.2	32.18
Rough Turn	20	251.47	15088.2	44.5
Final Turn	40	276.71	16602.6	50.2
1st Milling Op	50	225.33	13519.8	34
2nd Milling Op	60	73.29	4397.4	13.9
Final Inspect	65	8.67	520.2	15.3
3rd Milling Op	70	132.69	7961.4	27.1

Information Based On Recorded Values

Figure 6: Process times

MFGE-440 Presentation

Manufacturing Process Analysis of OEM Fabricators Inc.



Group 3: Aaron Arnold, Lucas Daul, Brett Krull, & Ryan Nebel

Figure 7: Simulation Model

RESULTS AND RECOMMENDATIONS

The developed simulation model was able to predict the actual throughput based on the existing set-up process. An effort was made to improve the production process by analyzing “What-If” scenarios. The model prediction results are shown in Figure 8. The Table 1 shows the process time reduction based on adding different resources to the existing process. The cost and other relevant information were not presented due to propriety information.

- Current State Model reflects a total time of 7,274 Minutes per run
- Adding an additional Lathe decreases run time By 1,704 Minutes (28.4 Hours)
- By Considering the overall cost of the equipment and layout of the company, an additional lathe would be the best solution

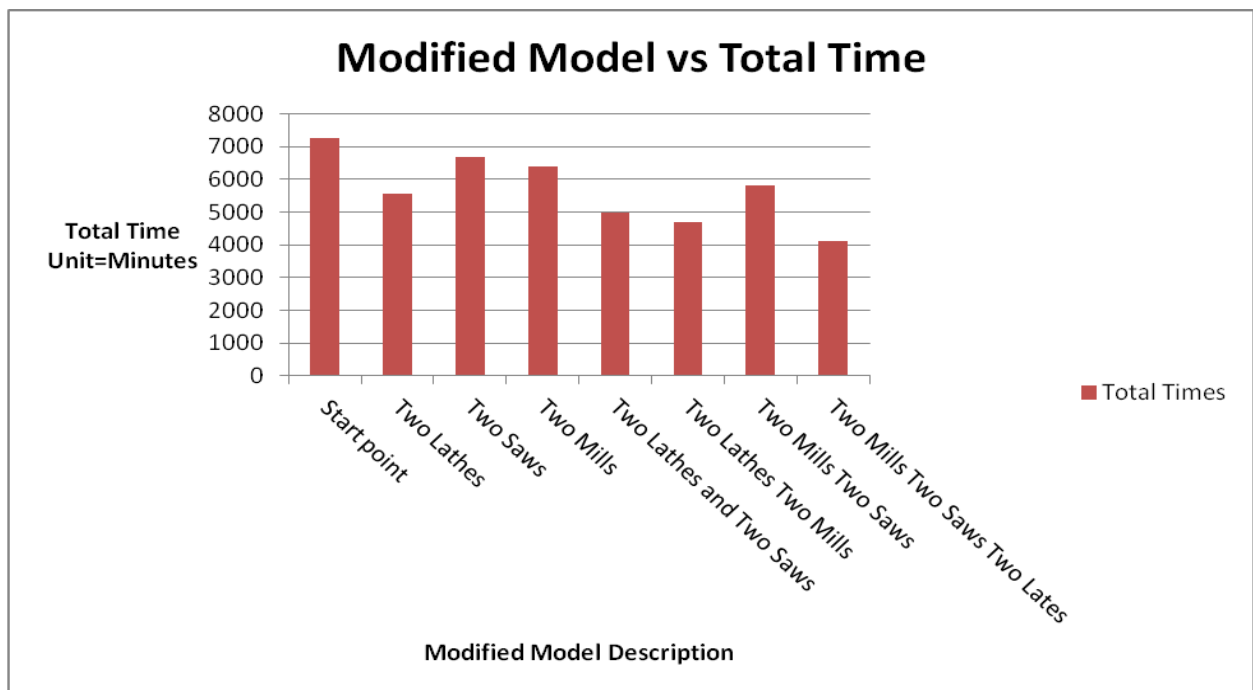


Figure 8: Model Prediction based on “What-If” scenarios

Table 1: Comparison of process time reductions

Description of Modification	Total time (Min)	Process Time Reduction
Start Point	7275	100%
Two Lathes	5570	77%
Two Saws	6695	92%
Two Mills	6412	88%
Two Lathes and Two Saws	4990	69%
Two Lathes Two Mills	4708	65%
Two Mills Two Saws	5833	80%
Two Mills Two Saws Two Lathes	4128	57%

In this study, the students were able to successfully apply the class room learning tool to the real world industrial problem solving.

ACKNOWLEDGMENTS

We would like to give our special thanks and appreciation for the reviewers for their constructive comments that helped us a lot to revise this paper.

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The Role of Computer Aided Engineering Software in Undergraduate Education

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Abstract

Analytical and experimental techniques have always been used to teach engineering concepts. The introduction of computer aided engineering (CAE) tools to the engineering classroom and curriculum have often been seen as excellent supplements to these traditional curricula and courses, but not necessary for a well rounded education. However, as CAE tools take a much larger role in every aspect of the engineering profession, is it time to consider the use of CAE as both necessary for all future engineers and essential to teach fundamental engineering concepts? This paper discusses these possibilities in the context of a mechanical engineering curriculum and specifically in the teaching of an introductory fluid dynamics course.

1 Introduction

Traditional engineering education has always included both analytical and experimental components as each has benefits for the student and for the practitioner. It is well understood that both analytical and experimental techniques in design, development, and validation are essential. These two approaches are valuable to teach aspiring engineers to use these techniques as an engineer, but also as a means of helping students understand fundamental concepts and techniques.

With the advent and maturation of both the digital computer and numerical techniques, computer aided engineering (CAE) software has added numerical simulation as a third approach commonly used by engineering professionals. Has the integration of CAE reached a level that it should be integrated into engineering curricula on par with analytical and experimental methods? Both advantages and disadvantages as well as barriers to integration of numerical simulations into curricula will be addressed. Although the concepts discussed have application over all engineering curricula, the discussion will be in the context of a mechanical engineering program and specifically at the the University of Wisconsin–Platteville in required introductory fluid dynamics and elective computational fluid dynamics (CFD) courses.

Any of these techniques, analytical, experimental, or computational, are valuable tools for the practicing engineer and included in a curriculum so that the future engineer can use the technique in the practice of their profession. However, a technique can also be used as a tool to teach a student concepts that might otherwise be more difficult for them to grasp. For example the energy equation is used by students to determine head loss through fluid systems because this is an essential technique for practicing engineers who design fluid systems. However, the same energy equation can help the students understand the transfer of energy between potential, kinetic, pressure (flow work), and thermal energy. The same is true for numerical simulations.

Future engineers need to understand the capabilities, limitations, and costs of using numerical simulations either in place or in combination with analytical and experimental methods. Pedagogically, a numerical simulation may better illustrate a concept or phenomena than will either analysis or experimentation.

2 Current CAE Curricular Integration

CAE has been integrated into most engineering curricula to different degrees depending on the discipline. In some cases CAE has completely replaced disciplines that were historically taught to all undergraduate students. In other cases it is solely at the instructors discretion whether to teach or use CAE in the classroom.

Computer aided design (CAD) software packages have universally replaced manual drawing techniques in virtually all engineering curricula. In fact, in most mechanical engineering programs, three-dimensional solid modeling packages have replaced two-dimensional CAD packages. In these courses, it clearly would be unacceptable for an instructor to ignore the CAD packages and teach traditional graphics techniques on a drawing board.

However, other computational packages have not replaced or even significantly augmented other areas of engineering education. Although most introductory fluid dynamics text books have at least one chapter devoted to CFD, typically include some illustrations derived from CFD analysis, and may include some supplementary material that allows students to explore fluid dynamic concepts using CFD, the books are organized and written so that the introductory course can be taught without mention of CFD.

This is not the case in the heat transfer course that typically follows this fluid dynamics course. Almost universally heat transfer texts include a chapter on either finite difference or finite volume methods of solving heat transfer problems. This is typically done independently of CAE packages. It is certainly appropriate that undergraduates are exposed to numerical methods on which CAE software is based, but is it appropriate to do while excluding commonly used CAE software packages from the discussion?

Engineering programs have sometimes struggled to determine at what level computer based subjects should be taught. Prior to the advent of commercial software packages like Matlab, Mathcad, Engineering Equation Solver, and Excel, not to mention modern CAE packages, most programs taught an introductory programming course. With the advent of these commercial packages, many programs including Mechanical Engineering at UW-Platteville removed the introductory programming as a requirement, choosing instead to invest these credit hours elsewhere. The pendulum may have started to swing back as it is found that upper level students struggle in things like mechatronics, data acquisition, or numerical methods that are taught in other courses. UW-Platteville has recently implemented a course that teaches introductory programming with an emphasis on algorithm development.

At least within Mechanical Engineering programs, CAE integration is uneven and uncoordinated. Instructor discretion, interest, and capabilities dictate at what level CAE is integrated into many classes. Will the requirements for quality engineers necessitate a more even and coordinated coverage in the future? Do we as faculty need to consider and plan our curricula

with CAE integration in mind? Do we need to rework our textbooks so that CAE techniques are not treated as supplemental but essential? When hiring a faculty member, do we have the same expectation of their ability to use and teach computational techniques as we do their ability to work analytically and experimentally? Should we have the same expectation? Is it critical for our faculty today? Will it be critical before these faculty members reach the end of their careers?

3 Motivations for Curricular Integration

Computer aided engineering (CAE) has gone through a maturation process from academic research interest, to specialty applications by government and the largest corporations with significant research and development capabilities, and finally to common use in moderate and even small companies. If CAE is going to take a larger industry role and impact the undergraduate student to a greater degree, it is important to understand the external and internal influences that will motivate curricular changes. The widespread industrial use of computational techniques may be an external motivator that forces its greater inclusion in curricula, whereas the pedagogical advantages may be internal motivators.

A significant external motivator occurred in the Mechanical Engineering program at the UW–Platteville in the Fall of 2007. We were notified, by a corporation that hires a significant number of our graduates, that unless we included solid modeling, numerical methods, finite element analysis (FEA), and CFD as required components of our program that this corporation would no longer recruit our graduates. This notice generated significant conversation and debate among the faculty. We clearly needed to respond to industry needs, but in a way that took into consideration the curriculum as a whole. Although CFD had been included as part of technical elective, this incident provided critical mass and accelerated the development of a technical elective devoted exclusively to CFD. The two-dimensional graphics course was replaced with a required course in solid modeling. An elective course in finite element analysis was and continues to be taught. Although less motivated by this incident, a course in algorithm development and programming has been added to the curriculum. In the end the relationship with this corporation has improved. They continue to actively recruit our graduates even though we included several of these techniques only as electives. Although this external motivator was an isolated instance, it demonstrated that there may be a need for greater CAE exposure at the undergraduate level.

This external motivator provided critical mass to spur several curricular changes and subsequently internal motivators became evident. As faculty members gained proficiency with several of these packages, the ability and opportunity to use them as pedagogical tools became apparent.

Into the 1980's kinematics was taught using graphical methods where scaled vector plots for velocities and accelerations were created. Interestingly, numerical techniques replaced these graphical methods due to the increased efficiency and accuracy of the solutions. The pedagogical disadvantage was that the loss of understanding by the novice due to the lack of a vectorial depiction. The UW-Platteville faculty member who developed the solid modeling course has revived many of the graphical techniques using the software introduced in this course. The advantage is that the same efficiency and accuracy of non-graphical methods is obtained with the advantages of the graphic construction.

I have begun using CFD simulations in the introductory fluid dynamics course, not in an attempt to teach students how to use the CFD software, but rather as a way of illustrating certain effects that are not as easily shown using analytical or experimental methods. The six exercises that are currently being used are:

1. An animation of an unsteady flow over a circular cylinder with both streak and stream lines displayed is used to illustrate that these two types of lines are identical in the steady region upstream of the circular cylinder, but deviate significantly in the unsteady wake.
2. A simulation of a flow over a reaward facing step is used to show under what circumstances Bernoulli's equation is applicable. Velocity magnitudes, pressures, and Bernoulli constants are extracted from the simulation at four different points to illustrate that Bernoulli's principle is valid along a stream line or in an irrotational flow, but is not valid when on different stream lines in a rotational flow. This simulation is used to introduce vorticity and its relation to losses in a flow.
3. When the integral momentum equation is initially introduced, students use Bernoulli's equation, for lack of any other method, in order to calculate the inlet pressure of a nozzle. This simulation illustrates the error introduced by making this assumption.
4. The effects of assuming a uniform velocity from a radial nozzle is explored. A CFD simulation shows, as seen in figure 1, that the velocity and water to air distributions vary significantly from the assumed uniform distribution. A thin sheet of water is flows out the bottom of this boundary while air is drawn into the nozzle thorough the upper part of this boundary. The CFD calculated momentum transfer is over 2.5 times that determined using the assumption of uniform flow
5. A series of four simulations show the effect of rate of convergence or divergence on the minor loss coefficient under conditions or adverse or favorable pressure gradients. Adverse and favorable pressure gradients are discussed and their impact on separated flow.
6. Flow over a blunt body and streamlined body are compared at different Reynold's numbers. Since it is possible to extract the frictional and pressure drag quantities separately, it is shown that streamlining decreases pressure drag and increases frictional drag. By looking at both low and high Reynold's number cases it is shown that reduction in the pressure drag dominates the increased friction drag at high Reynold's numbers, whereas the opposite is true at low Reynold's numbers.

The purposes of these exercises fall into two categories of illustrating a principle (numbers 1, 5, and 6) and investigating the simplifying assumptions made in the process of developing an analytical model (numbers 2, 3, and 4). The illustrations of 1 and 6 are virtually impossible to perform analytically or experimentally. The illustration of number 5 could be performed experimentally but at much greater cost and effort. The graphical nature of simulation 1 makes obvious a concept that many novices have difficulty grasping. The ability to separate the pressure and frictional drag in simulation 6 provides a unique explanation of the phenomena.

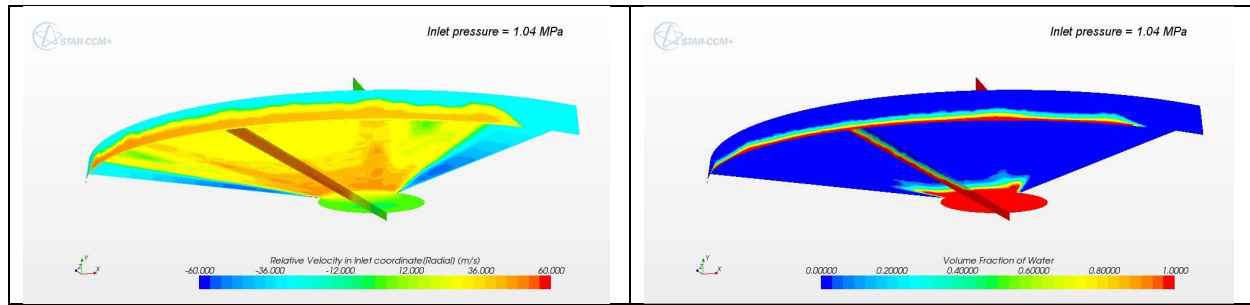


Table 1: Left: Velocity distribution in a radial nozzle. Right: Volume fraction of water in a the same nozzle. Note that neither of the quantities is uniform over the radial exit boundary. For simplicity of analytical computation, students were instructed to assume a uniform velocity distribution resulting in error greater than 250%

Simplifying assumptions are frequently made to create mathematically tractable models that can be solved analytically. We have an obligation to students to illustrate the potential deficiencies inherent in making these assumptions. The ability to quickly and inexpensively numerically simulate conditions where these assumptions are relaxed gives the students insight into the effect of the simplifying assumption. They see that in some cases the assumptions have little impact whereas in others significant error is seen as in number 4 above.

4 CAE Integration: Issues and Barriers

Due to these positive and negative motivations the pressure to use CAE software in the undergraduate curriculum will likely increase in the future. Along with the positive aspects of having additional tools to teach with and exposing students to modern tools used in engineering work, there are issues which include inspiring faculty to learn and use these tools, how to appropriately implement these tools into the curriculum, and deciding which software packages are best to use. These three issues are not mutually exclusive. The implementation may be dependent on which software is chosen which in turn may be influenced by faculty preference and software capability and popularity. Although there may not be one optimal set of choices that best addresses these issues, there are likely some best practices that should be encouraged and worst practices that should be avoided.

4.1 Faculty capabilities

Predictably the faculty who are most engaged in integrating simulation software in the Mechanical Engineering program at UW–Platteville are faculty who had a strong computational background. All of the faculty have an adequate understanding of the theoretical concepts on which the computer simulation software is based. However, the majority of them are not proficient with the commercial CAE packages that are available within the department and therefore are unable to easily incorporate their use within required courses. The greatest barrier to incorporating computational simulations into the classroom setting are the perceived non-financial costs. In most cases there is a significant initial learning curve and continued effort to stay current with many commercial software packages. Although it took me approximately a

day to create the simplest CFD models when I first tried a commercial CFD package, it has taken hundreds of hours of work to become proficient with many other the more advanced features in the package. This effort was only put forth because I teach the CFD technical elective. However once this proficiency is gained, applications, like the six previous mentioned exercises to more fundamental thermal fluids courses become evident and possible.

It has been my experience that teaching students to learn the software package is the best way of forcing myself to become proficient with that package. As the CFD course evolved, I desired to teach students to create models with greater geometric complexity. However, I was not proficient enough with the solid modeling package to create the required geometries. In order to force myself to become more proficient, I volunteered to teach the introductory solid modeling course. As a result, not only am I able to create the complex geometries required for the CFD elective course, but I find it a valuable tool in other activities.

Perhaps another way of allowing faculty to include numerical simulations in their course is through team teaching. A colleague who regularly teaches the thermal systems design course devotes approximately a week to CFD. I initially helped him develop lecture material for this portion which he feels comfortable presenting. For the hands on experience of creating a simple CFD model I have either led the computer laboratory exercise or alternatively prepared podcasts that the students can follow either individually or as an entire class. Since there are always at least a few students in this class that either previously or are concurrently enrolled in the CFD elective course, they serve as teaching assistants to help their fellow students when they run into issues running the software.

4.2 CAE Curricular Integration Issues

All engineering programs are constrained by the number of credit hours and the content that never seems to fit within these credit hours. Additionally, there are preferable ways of including this material.

If numerical simulations are going to eventually be emphasized as strongly as analytical and experimental techniques what courses will be eliminated on the coarse scale and/or which content will be eliminated from current courses on the finer scale? Should CAE be segregated into dedicated courses or integrated into courses that have traditionally emphasized analytical solutions? Some curricula are designed to have lecture courses and lab courses, thus divorcing the experimental techniques from the analytical techniques. Other curricula are designed with coordinated lecture and laboratory components within a single course. The curricular integration of numerical simulations could be accomplished by following either of these two paradigms.

At UW-Platteville, there have been no institutional decisions made regarding the inclusion of numerical simulations into the curriculum on par with analytical and experimental techniques. Since the CFD course at UW-Platteville is a technical elective no material has been eliminated from the curriculum, but only a minority of the students are taught to effectively use CFD in this course. In the introductory fluid dynamics course my efforts have focused on integrating numerical simulations into the lectures. In these efforts I have not eliminated any material from the course. The results of the six previous simulations have replaced lecture material that illustrated the same points in less effective ways. Currently the students do not perform the

simulations. I plan on moving these simulations from the current passive form to active learning exercises that allow the students to explore concepts.

Class time for these exercises has been created by flipping one of three hour lectures each week. The lecture material is recorded as a podcast and the students are required to watch and take notes on this presentation on their own time. The liberated class time has been used to provide recitation and perform experiments and demonstrations. In the upcoming semester I plan to move at least two of the previously mentioned six simulations to active learning exercises where the students interact with the simulation software during this time in an appropriate environment

Creating this appropriate environment is critically important. Although the graphical user interfaces (GUI) on modern numerical simulation software has made it much easier to set up, run, and post process simulations there are still many essential decisions in creating a model that are not eliminated by GUI's. I have been reluctant to create assignments in the introductory fluid dynamics course that require students to interact with the simulation software. This reluctance stems from two concerns: 1) Students will be distracted by the details of interacting with the software and completely miss the fluid dynamics point that the simulation was to illustrate; and 2) Since it is much easier to learn to run the software than to make good modeling choices, introductory students may become overconfident in the abilities to create simulations and subsequently create CFD models with gross errors.

Most engineering students are strategic learners, meaning that they will work hard at learning something if it achieves their goals, like earning a desired grade. (Entwistle, N. and Ramsden, P. 1983). Strategic learners, however, may not independently think about the results of the exercise and thus not come to the desired conclusions. This may result in some students successfully completing the simulation, but missing the point that the instructor intended the student to learn. Carefully planned follow up exercises are often required to help students draw these conclusions. Both written and interactive classroom formats have been attempted. The advantages of the written follow up exercises is that it forces each student to think about the implications of their observations, whereas a classroom discussion can be dominated by a few outgoing, engaged students allowing the majority to sidestep the critical thinking process. The disadvantage of the written format is that students will often write as little as possible to fulfill the requirements of the assignment. Perhaps a combination of the two provides an optimal learning environment.

Training students to run a software package in a context that excludes emphasis on modeling choices is dangerous. My experience is that it is much easier to teach a student to run a software package than it is to teach them to make good modeling choices. Giving students step-by-step instructions to create a simulation in order to illustrate a certain point may inadvertently cause the student to think they can successfully model a very different scenario by making the same choices. When simulation software is used in an introductory course to illustrate a certain point, measures should be taken to ensure that students have the proper perspective on their abilities. Several possible means of accomplishing this is by constructing the model for the student and having the student change a small number of critical parameters, or taking the time to explain why each of the modeling choices were made.

4.3 CAE Software Requirement

The third issue involves choosing the best simulation software for a given curriculum or situation. The software needs to be able to meet the needs of both the student and faculty. Factors that influence this decision include cost, familiarity, popularity, support, scalability, teachability, ease of learning, consistency, and capability. Although failure to minimally fulfill any one of these criteria may lead to unsuccessful implementation, some of these factors may not be considered when initially choosing a software package.

If a software package is too difficult for a faculty to learn, too difficult to teach to students, or lacks consistency over time it may not be an effective tool for the classroom. Faculty may use these packages intensely for a few months when teaching a certain course, but then may have little need for it otherwise. It may be difficult for the faculty to stay current if the GUI changes significantly from one release to another. In the case of CFD software packages, many grew out of combining research codes that were each designed to simulate a specific flow regime or scenario. Since there was no unified design that linked these codes they lacked consistency between flow regimes and from one software version to another. For example you might need to generate a computational mesh using a one method when simulating a compressible flow as opposed to another with modeling an incompressible flow. These may make it impossible for a faculty member to learn, maintain their proficiency with, and ultimately teach students this software.

Some software is designed for strictly pedagogical purposes. These are typically a compromise between ease of use and capability, scalability and popularity. These packages may serve the pedagogical needs while failing to meet the needs of scalability, popularity, or support. Students may struggle to use these tools effectively in subsequent courses, like a capstone design course, if the software does not scale to larger, more complex problems. Lack of popularity or support may result in the software or its support becoming discontinued.

The CFD software used at UW-Platteville was initially chosen based on cost, support, teachability, ease of learning, and capability. Fortunately, the software has met the other requirements as well. When initially adopted the software was in its development infancy and barely met the capability requirements. Over the six years since it was adopted, because of the initial software design, it has grown in capability and scalability to a point where it more than exceeds any pedagogical need. It has a consistent and unified model setup, meshing, and post processing tools along with appropriate solvers. The GUI has remained consistent with few changes except the addition of new capabilities. These features have allowed me to continually build my modeling capabilities using previously gained knowledge about the software. I routinely add content to the elective CFD course. I am able to focus on the theoretical basis of how the software works and on appropriate modeling choices while still teaching the details of how to interact with the software. Because the software is used widely in industry I have been able to arrange guest speakers in the elective course.

5 Conclusion

Numerical simulation software is being used at an ever increasing rate within engineering practice and is commonly used in conjunction with analysis and experimentation to develop, design, and innovate. Thus it is appropriate to expose future engineers to these tools. It has been used successfully as a tool that may be more effective in teaching fundamental concepts in introductory courses. There are no known cases where it is being integrated into any curriculum

on par with analytical and experimental methods. Are we reaching the point where this integration is appropriate or even necessary? Issues concerning this type of integration were explored including how to inspire faculty to learn and integrate this inquiry method, how to best integrate it into an established curriculum, and what requirements might a software package need to meet in order for it to be successfully used as a pedagogical tool.

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The Computer-Aided Microwave Design System (CAMDS): Implementation and Verification

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Abstract

This work presents the current progress in development and application of the Computer-Aided Microwave Design System (CAMDS). The paper focusses on passive devices using microstrip transmission lines such as filters or stub tuners. Designs developed with CAMDS are compared with those reported by Pozar, simulated using the Agilent Advanced Design System (ADS), and then fabricated using an ADS layout. In appropriate cases, device performance is checked using independent computer analysis or measurement of the device response using a microwave network analyzer. The main result is rigorous verification of its capabilities to produce useful designs for practical passive microwave devices.

Introduction

The purpose of this paper is to present the logical continuation of the work of Bais¹ in a thesis developed at North Dakota State University (NDSU). That thesis had as its purpose the development of software that would perform the mathematical design and analysis that is found in microwave engineering textbooks (for example, the well-known textbook by Pozar²) commonly used for senior electives and graduate courses. The current paper focusses on passive microwave devices that are suitable for fabrication in microstrip. The first concern is to verify the design and analysis that can be obtained from the CAMDS software. So in each case mentioned in this paper, the code developed by Bais was checked and in some cases improved.³

CAMDS includes design and analysis software for microstrip transmission lines themselves along with various applications. The applications include single-stub tuners (series and shunt), double-stub tuners, L-match tuners, filter design by Kuroda's method, and stepped-impedance filter design. The work reported earlier by Bais involved code development and test. The next step in this work would be fabrication of several of these devices. An intermediate step would be to utilize a package like the Agilent Advanced Design System (ADS)⁴ to design or analyze the same devices covered by CAMDS.

The availability of ADS provides three possibilities. First, devices produced using CAMDS for the design can be comprehensively simulated by ADS without the fabrication step. The fabrication and testing step can be very time consuming. Simulation of the CAMDS device using ADS is a very economical way of checking the validity of the CAMDS results. Second, ADS can be used directly to produce its own design of a microwave device. Thus the results can be compared to the performance of the same device as developed by CAMDS. The designs usually are not the same because the design decisions implemented in ADS are not always the

same as those found in CAMDS. Finally, a device designed either through CAMDS or ADS can be fabricated using the control algorithm that is available in ADS.

The Scattering Parameters

The scattering parameters (sometimes called the S-parameters) are often used in this paper. Pozar² presents an extensive discussion of what is commonly known about the S-parameters. The only S-parameter components used in this paper are referred to as S_{11} and S_{21} . S_{11} is the voltage reflection coefficient at the input of a two-port device. Often it is desired that the device match the impedance of the system. If this is the case, the magnitude of S_{11} will be small or, ideally, zero. S_{21} is very useful since it requires that the source impedance and the load impedance of the device be the system characteristic impedance, Z_o . This is the situation almost universally seen in this work. S_{21} is the ratio of the backward traveling voltage from the perspective of the output port to the forward traveling voltage at the input port. This is commonly referred to as the voltage gain. It is conveniently expressed in dB. S_{11} is the voltage reflection coefficient at the input given that the output is matched. The focus of this paper is that situation in which whatever simple or complicated device might be under study, it will be studied under matched conditions.

If the output voltage is greater than the input voltage, S_{21} in dB will be greater than zero. This is often the case in active devices. If the output voltage is less than the input voltage, S_{21} in dB will be less than zero. This is most common with passive devices. For passive devices we often refer to the attenuation of the device. For the devices considered in this paper, the attenuation is simply the absolute value of S_{21} in dB.

Coding Microwave Device Models for Computer Analysis

The CAMDS applications of interest in this paper are the design of microstrip transmission lines, the L-match lumped-circuit matching device, and the stepped-impedance low-pass filter.

The CAMDS microstrip routine provides the effective dielectric constant of a desired line when it is provided with the dielectric constant of the circuit board and the desired transmission line characteristic impedance. User instructions for CAMDS are available in the works by Bais,¹ Sharma,³ and Bais and Rogers.⁵ The process is also demonstrated later in this paper for the case of the stepped-impedance filter. For example, the designer requires a 50- Ω line that is fabricated on a circuit board with a dielectric constant $\epsilon_r = 4.2$ at a frequency of 1.5 GHz. CAMDS provides the following output:

The Relative Permittivity is= 4.2
The characteristic impedance is 50
The effective dielectric constant is 3.20203
W/d ratio is 1.97914
Operating Frequency in Hz is 1.5e+009
k0 per meter is 31.4159
The angular velocity in rad/sec is 9.42478e+009
Phase velocity vp in m/s is 1.67652e+008

Guide wavelength λ_g in meters is 0.111768
 Beta in radians per meter is 56.2163
 Filling Factor in Hz is 0.902604
 Capacitance per unit length of the line in farads is 1.19295e-010.

The key item here for use in the design and analysis of devices in this paper is the effective dielectric constant, ϵ_e , which is returned as 3.20203.

Often of concern to the designer is an impedance matching network. CAMDS designs the well-known L-match network given the source impedance, the load impedance, and the design frequency. As an example, consider a source impedance of 50- Ω , a load impedance of 100- Ω , and an operating frequency of 1.5 GHz. The L-match routine returns:

The load impedance is 100
 The characteristic impedance is 50
 The load is inside 1+jx circle in Smith Chart

SOLUTION1

b on Smith chart is at 0.5
 x on Smith Chart (reactance) is at 1
 B is a capacitor of value in farad 1.06103e-012
 X is a inductor of value in henry 5.30516e-009

SOLUTION2

b on Smith chart is at -0.5
 x on Smith Chart is at -1
 X is a capacitor of value in farad 2.12207e-012
 B is a inductor of value in henry 1.06103e-008

The first solution is a series inductance of value 5.30516 nH and a shunt capacitor of value 1.06103 pF. The second solution is a series capacitance of value 2.12207 pF and a shunt inductor of value 10.6103 nH.

To write a standard computer code to model the L-match device, consideration of a cascade of components is necessary. Using the order of load to source, the first element is a quarter-wavelength impedance transformer that would change a standard laboratory impedance of 50 Ω to be a test impedance of 100 Ω . The ABCD matrix for this device is

$$A_{line} = \begin{bmatrix} \cos(\beta l) & jZ_0 \sin(\beta l) \\ \frac{j \sin(\beta l)}{Z_0} & \cos(\beta l) \end{bmatrix},$$

where l is a quarter wavelength and $\beta = 2\pi/\lambda_{guide}$ (λ_{guide} is the guide wavelength). The computer model of the ABCD matrix of this device is

```
Aline=[cos(beta(ii)*len) 1 j*Zoline*sin(beta(ii)*len);
1j/Zoline*sin(beta(ii)*len) cos(beta(ii)*len)]
```

The expression for beta is provided earlier in the code as

$$\text{beta}=2*\pi/c*\text{sqrt}(\text{epse})*f$$

where epse is the above-mentioned effective dielectric constant, c is the speed of light, and f is the frequency in hertz. The variable len is the length of the quarter-wavelength microstrip line at the design frequency. Each of the elements used in this paper can be represented in a similar way as shown in Table 1.

Table 1. Computer Code for Microwave Device Elements

Element	Computer Code for ABCD Matrix
Series Resistor	AR=[1 R;0 1]
Series Inductor	AL1=[1 1j*2*pi*f(ii)*L1;0 1]
Shunt Inductor	AL2=[1 0; -1j/(2*pi*f(ii)*L2) 1]
Shunt Capacitor	AC1=[1 0;1j*2*pi*f(ii)*C1 1]
Series Capacitor	AC2=[1 -1j/(2*pi*f(ii)*C2); 0 1]
Transmission Line	beta=2*pi/c*sqrt(epse)*f(ii) Aline=[cos(beta(ii)*len) 1j*Zoline*sin(beta(ii)*len); 1j/Zoline*sin(beta(ii)*len) cos(beta(ii)*len)]
Open-circuited Stub	beta=2*pi/c*sqrt(epse)*f(ii) Aline=[1 0;1j/Zoline*tan(beta(ii)*len) 1]

The L-match can be modeled by using the 100-Ω test impedance as the load. Working back from the load, series or shunt reactances as shown in Table 1 are used to complete the model of the devices. The stepped-impedance transformer computer model uses a cascade of several different transmission lines.

Useful Matrices

The devices mentioned in this paper that have been designed using CAMDS can be verified or analyzed with computer programs written using standard computer code. Each device can be viewed as a cascade of two-port devices⁶ or as the parallel combination of two or more cascades of two-port devices. Each device can be characterized by its ABCD or “chain” matrix. A cascade of devices can be viewed as the overall ABCD matrix formed by the product of each individual ABCD matrix taken one by one from source to load. In the case of a parallel

combination of two cascades, the two overall ABCD matrices can be combined by first converting each to an overall admittance matrix (or Y-matrix) and then by using the well-known result that the combined overall admittance matrix will be the sum of the two individual overall admittance matrices. Since we are usually interested in the scattering parameters, the combined overall admittance matrix is then converted to a scattering matrix. Each additional parallel cascade can be accounted for by adding its admittance matrix to the previously obtained combined admittance matrix. From the combined matrix the individual elements of the scattering matrix can be calculated using well-known procedures.²

Considering the matched conditions mentioned previously, the device input impedance as a complex number can be calculated directly using S_{11} . The device designer then analyzes the input impedance as a function of frequency to evaluate the merit or utility of a certain type of matching device such as a single-stub tuner. At the same time, the designer can view S_{21} in dB to investigate the transmission characteristics of the device. In the case of a filter or a coupler, usually S_{21} in dB is of primary importance while S_{11} is of secondary importance. For a filter, S_{21} in dB should be zero in the passband and negative outside of the passband. Often the value of S_{21} in dB at the transition point between passband and stopband (or band edge) is specified at a cutoff frequency. Two typical examples of this are the stepped-impedance filter or the filter constructed using stubs. For a coupler such as the ninety-degree quadrature hybrid, S_{21} in dB will be 3 dB below the input signal at the usual output ports and nonexistent in the isolated port ($S_{21} = 0$ or S_{21} in dB approaches negative infinity).

Stub tuners (single- or double-stub tuner) lend themselves nicely to analysis using the chain matrix followed by conversion to S-parameters. Conversion at a particular frequency is available in CAMDS, but conversion over a range of frequencies is best accomplished through an individual MATLAB routine written specifically for that purpose.

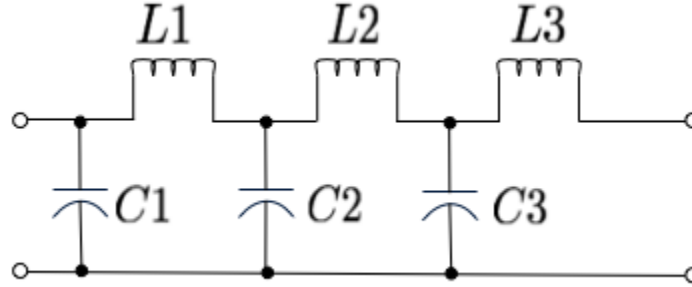
Computer Verification of the CAMDS Procedure for the Stepped-Impedance Filter

A major element of the CAMDS package is the design of the stepped-impedance filter. CAMDS accepts the low-pass filter prototype element values and provides the design for the stepped-impedance implementation of a low-pass filter. An example in Pozar² was chosen in which a maximally flat frequency response and a cutoff frequency of 2.5 GHz are desired. A 20-dB insertion loss at 4 GHz is required. The logical choice is a filter of sixth order. The system characteristic impedance is 50 Ω . Implementation in microstrip allows the use of impedances in the range of approximately $20 \leq Z_o \leq 120 \Omega$.

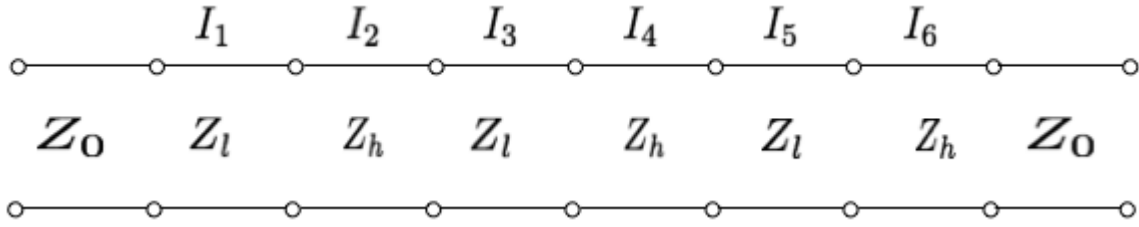
The stepped-impedance filter is a low-pass filter that can be implemented in microstrip. It uses alternating very high and very low characteristic impedance lines. It is also referred to a “hi-Z and low-Z” filter. It is superior to a low-pass filter designed using stubs since it uses less space and is easy to implement.

In the stepped-impedance filter, the series inductors of a low-pass prototype are replaced with a high characteristic impedance line with $Z_0 = Z_h$ and shunt capacitors are replaced by a low impedance section with $Z_0 = Z_l$. The ratio Z_h/Z_l should be high.

The development of the stepped-impedance filter from a lumped-element circuit sixth-order prototype to the microstrip implementation is shown in Fig. 1. The first microstrip element will be capacitive. A standard copperclad sheet of thickness $d = 0.158 \text{ cm}$ and dielectric constant $\epsilon_r = 4.2$ was used.



(a) Sixth-order low-pass filter prototype.



(b) Stepped-impedance implementation.



(c) Microstrip-line filter layout.

Fig. 1. Progression from: (a) sixth-order lumped-element prototype through (b) transmission-line equivalent circuit to (c) microstrip implementation of a stepped-impedance filter.

The detailed values obtained for the stepped-impedance low-pass filter using Pozar are listed in Table 2.

Table 2. Stepped-Impedance Filter Element Dimensions.

Section	Characteristic Impedance (Z_i) in ohms	Electrical Length βl_i	Microstrip Width (W_i) in mm	Microstrip Length (L_i) in mm
1	20	11.8°	11.3	2.05
2	120	33.8°	0.428	6.63
3	20	44.3°	11.3	7.69
4	120	46.1°	0.428	9.04
5	20	32.4°	11.3	5.63
6	120	12.3°	0.428	2.41

The values given in Table 2 were confirmed independently using CAMDS, ADS and MATLAB. The design was simulated using ADS. This yielded the results described below.

The section that follows presents this same example problem using CAMDS. It also explains the steps necessary to study such a filter problem using the CAMDS software. To review, the user intends to design a stepped-impedance low-pass filter having a maximally flat response with a cutoff frequency of 2.5 GHz and a 20-dB insertion loss at 4 GHz. The system impedance is given as 50 Ω , the highest line impedance is given as 120 Ω , and lowest line impedance is 20 Ω . A microstrip substrate having thickness, d , of 0.158 cm and a relative permittivity, ϵ_r , of 4.2 was to be used.

The steps to solve the above problem using CAMDS are as follows.

- 1) Select “Stepped Impedance Low Pass Filter” from StartHere.fig and then press Go (as explained in detail in Bais and Rogers⁵).
- 2) Enter the order of the filter. In the above problem the order of the filter is 6 as shown in Fig. 2.

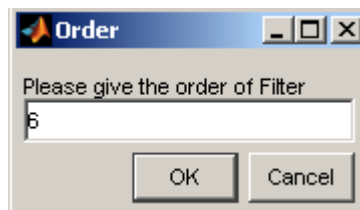


Fig. 2. Box to input the order of the filter.

- 3) Enter the filter impedance as shown in Fig 3.

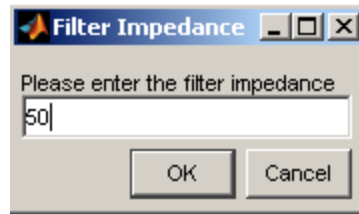


Fig. 3. Box to input the filter impedance.

- 4) Enter the highest practical line impedance. In the above problem it is given as $120\ \Omega$ as shown in Fig. 4.

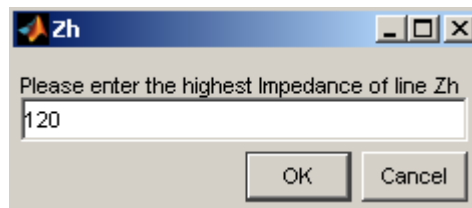


Fig. 4. Box to input the highest practical line impedance.

- 5) Enter the lowest practical line impedance. In the above problem it is given as $20\ \Omega$ as given in Fig. 5.

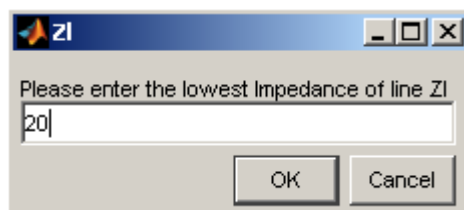
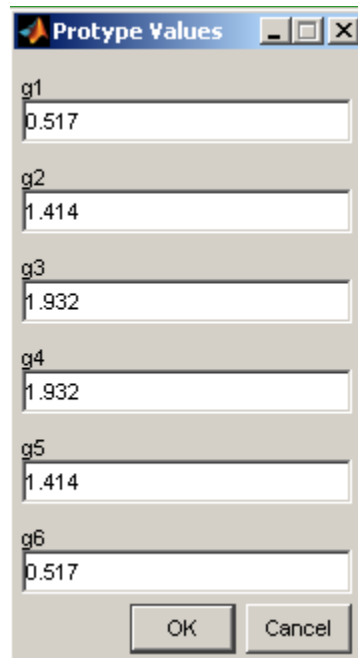


Fig. 5. Box to input the lowest practical line impedance.

- 6) Enter the prototype values for the given problem as shown in Fig 6. A table of prototypes values is given in Pozar.²

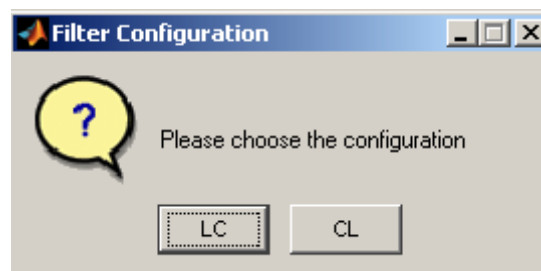


A dialog box titled "Prototype Values" with a standard Windows window border. It contains six input fields, each preceded by a label: g1, g2, g3, g4, g5, and g6. The values entered in the fields are 0.517, 1.414, 1.932, 1.932, 1.414, and 0.517 respectively. At the bottom right are "OK" and "Cancel" buttons.

Label	Value
g1	0.517
g2	1.414
g3	1.932
g4	1.932
g5	1.414
g6	0.517

Fig. 6. Box to input the prototype value.

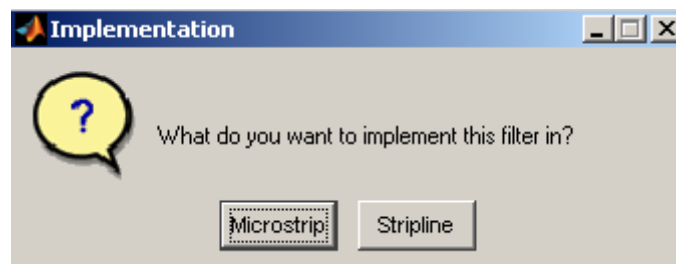
- 7) Choose the CL configuration for the above problem as in Fig. 7.



A dialog box titled "Filter Configuration" with a standard Windows window border. It features a yellow speech bubble icon with a question mark on the left. To the right of the icon is the text "Please choose the configuration". Below this text are two buttons: "LC" and "CL". The "CL" button is highlighted with a dashed border, indicating it is the selected option.

Fig. 7. Question box.

- 8) As shown in Fig. 8, choose Microstrip.



A dialog box titled "Implementation" with a standard Windows window border. It features a yellow speech bubble icon with a question mark on the left. To the right of the icon is the text "What do you want to implement this filter in?". Below this text are two buttons: "Microstrip" and "Stripline". The "Microstrip" button is highlighted with a dashed border, indicating it is the selected option.

Fig. 8. Question box.

- 9) Enter the relative permittivity. For the above it is 4.2. Fig. 9 below shows the input box for the relative permittivity.

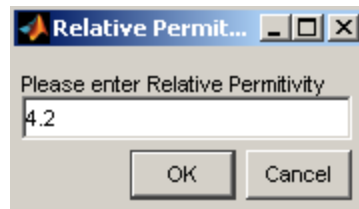


Fig. 9. Box to input the relative permittivity.

- 10) Enter the thickness as 0.158×10^{-2} as given in the problem. Fig. 10 shows the input box for the thickness.

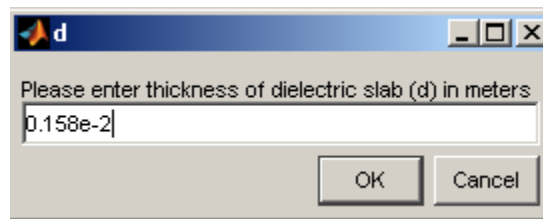


Fig. 10. Box to input the thickness.

- 11) Enter the value of the operating frequency as 2.5 GHz is shown in Fig. 11.

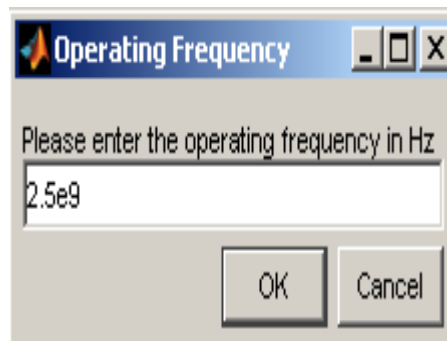


Fig. 11. Box to input the operating frequency.

The output that was obtained in the command window is as follows.

The order of filter is 6
The Filter impedance is 50
The highest line impedance is 120
The lowest line impedance is 20

The filter configuration is CL
Filter is implemented on a microstrip
The Relative Permittivity is 4.2
The dielectric slab thickness in meters is 0.00158
The operating frequency in Hz is 2.5e+009

For element of prototype value = 0.517 Impedance = 20 Ohms electrical length = 11.8488 degrees width = 0.011268 meters length=0.0020883 meters

For element of prototype value = 1.414 Impedance = 120 Ohms electrical length = 33.7568 degrees width = 0.00043025 meters length=0.0066789 meters

For element of prototype value = 1.932 Impedance = 20 Ohms electrical length = 44.2782 degrees width = 0.011268 meters length=0.007804 meters

For element of prototype value = 1.932 Impedance = 120 Ohms electrical length = 46.1231 degrees width = 0.00043025 meters length=0.0091257 meters

For element of prototype value = 1.414 Impedance = 20 Ohms electrical length = 32.4065 degrees width = 0.011268 meters length=0.0057116 meters

For element of prototype value = 0.517 Impedance = 120 Ohms electrical length = 12.3425 degrees width = 0.00043025 meters length=0.002442 meters.

From CAMDS the designer thus obtains the width and length of each microstrip element of the filter. This information can be used for fabricating the device, and this same information can be incorporated in a separate computer code. The microstrip thickness and width information can be used in the CAMDS microstrip routine to obtain the effective dielectric constant of each line for use in the computer simulation. This constant along with the element lengths makes it possible to simulate the performance of the microstrip implementation by using the ABCD matrices for the individual lines and then to obtain the overall scattering matrix, as will be shown in later. The low-pass prototype element values will also be used later to simulate the performance of a hypothetical lumped-element version of the low-pass filter.

ADS is gradually being used more and more in applied electromagnetics courses.⁷ The schematic for the stepped-impedance problem (Fig. 12) which was generated using ADS uses a function (var function) which is a tuning function used in the ADS software. When we simulated the schematic without the var function, the response which we obtained was different from that of Pozar² and from the MATLAB result. Example 8.6 in Pozar specifies that there be more than a 20-dB insertion loss at 4 GHz. ADS did not obtain this result. Thus the var function was used to tune the values of the lengths and the widths to obtain the desired response. The difference from the response obtained with the original schematic was because the values of width and length given in Pozar cannot generate the same response with more than 20 db insertion loss at 4 GHz when it is applied practically. So the var function tunes the values of length and width to obtain a cutoff frequency of 2.5 GHz and a 20-dB insertion loss at 4 GHz.

The new values for length and width that were obtained using the tuning function to obtain the response as given in Pozar are shown in Table 3.

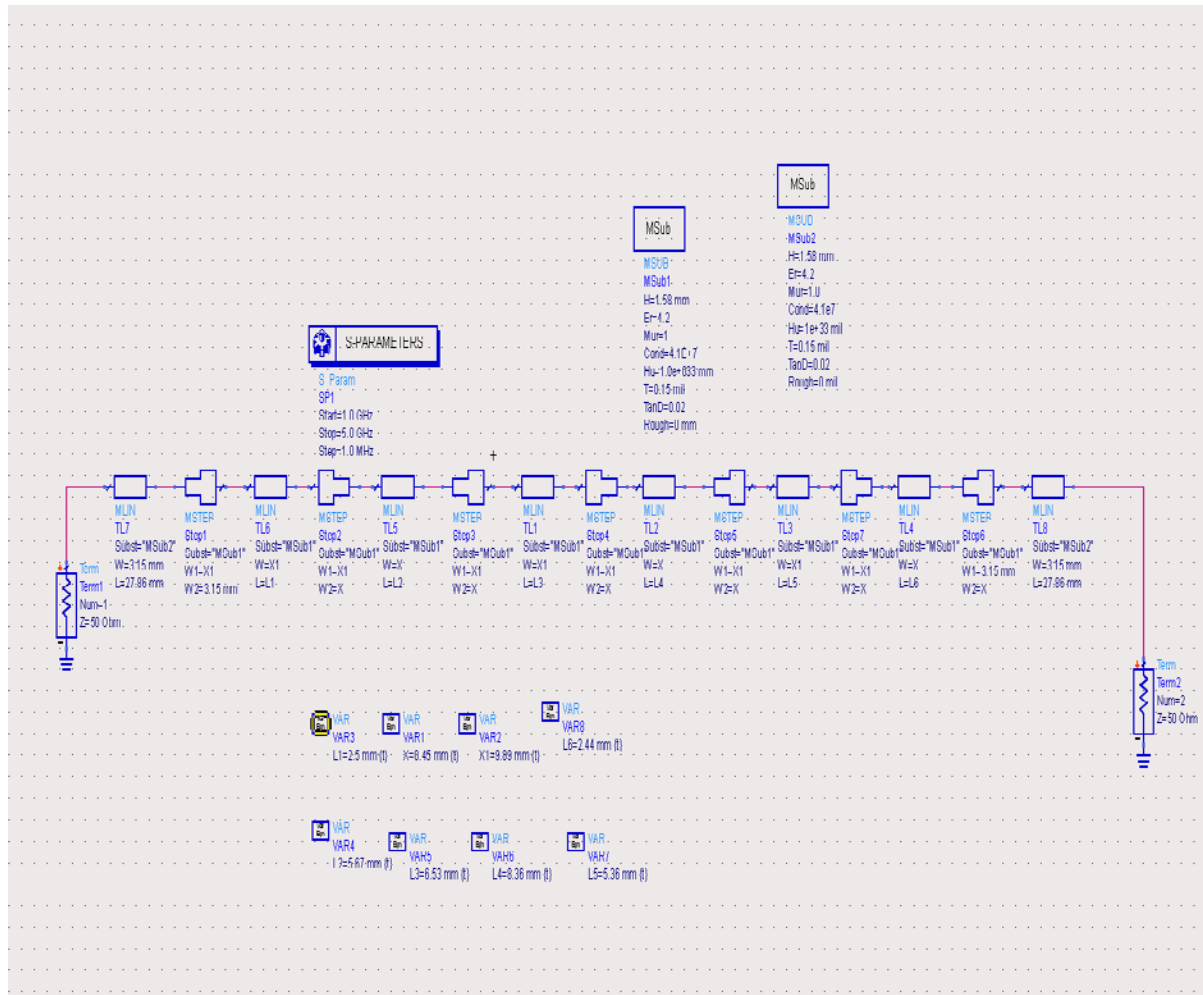


Fig. 12. ADS schematic of stepped-impedance filter.

Table 3. Filter dimensions as determined by ADS.

Section	Microstrip Width (W_i) in mm	Microstrip Length (L_i) in mm
1	9.89	2.50
2	0.45	5.67
3	9.89	6.53
4	0.45	8.36
5	9.89	5.36
6	0.45	2.44

The lengths and widths vary only slightly from the values given in Pozar. The ADS layout of the stepped-impedance filter is shown in the Fig. 13. ADS is able to compensate for edge effects at the junctions between elements and for the modal effects of the low-impedance elements.

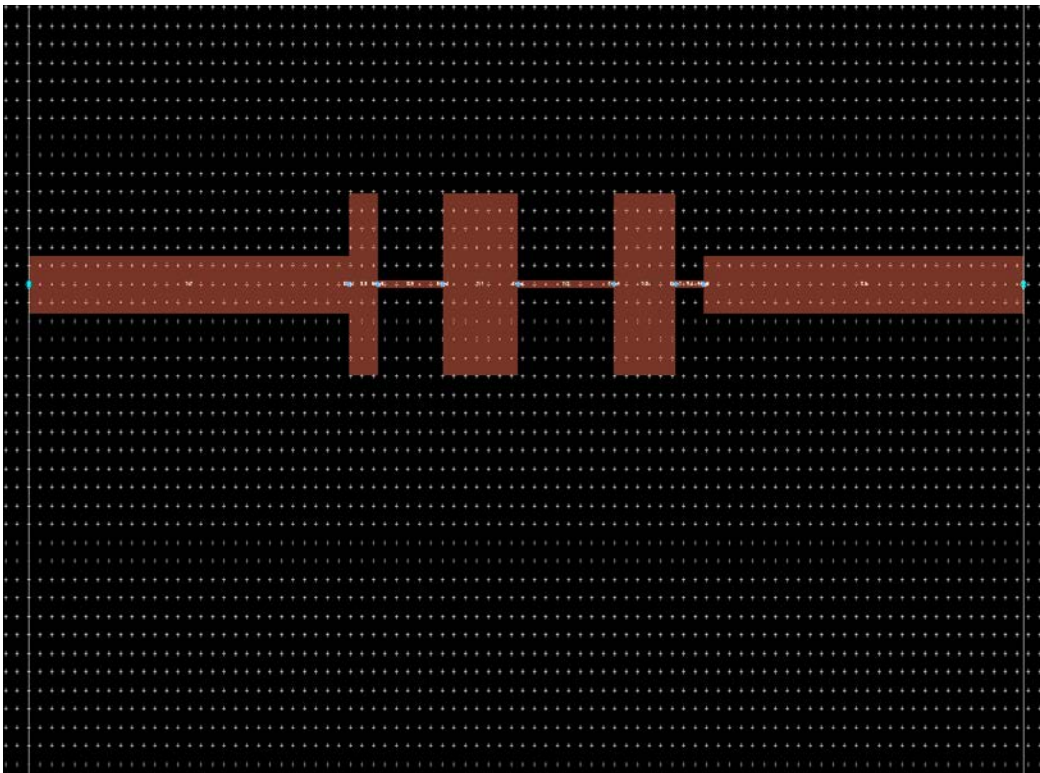


Fig. 13. ADS layout of stepped-impedance filter.

The ADS program also provided an analysis of the device performance as shown in Fig. 14. The response obtained has a cutoff frequency of 2.5 GHz and 20-dB insertion loss at 4 GHz. Fig. 14 is taken directly from ADS. Of particular interest is S_{21} expressed in dB or $20 \log_{10} |S_{21}|$. This is shown in Fig. 14 and indicated as dB(S(2,1)).

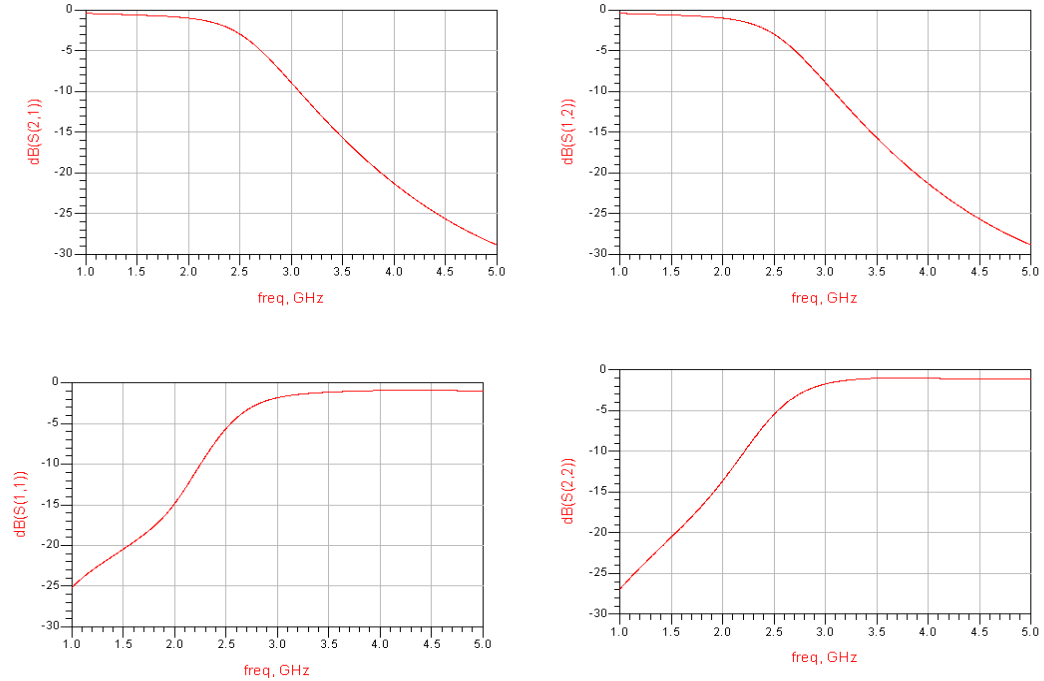


Fig. 14. ADS calculations for the scattering parameters S_{11} , S_{12} , S_{21} and S_{22} , expressed in dB.

The device layout shown in Fig. 13 is one that can be constructed using commercially available copperclad circuit board. The analysis shown in Fig. 14 is reasonably consistent with the theoretical predictions reported by Pozar. As Pozar states, the microstrip implementation is within about 0.5 dB of the lumped-element simulation for the frequency range 0 to 3 GHz. As the frequency increases from 3 GHz to 4 GHz, the microstrip implementation continues to serve as a low-pass filter but the attenuation is reduced by a few dB. These statements by Pozar were verified using MATLAB and the result is presented in Fig. 15. Above 4 GHz the microstrip implementation performance deteriorated substantially as can be seen by comparison of Fig. 15(a) and Fig. 15(b). Using the matrix methods described earlier in this paper, Figs. 15(a) and 15(b) were obtained by using the ABCD matrix of the each element, computing the product of the cascade of ABCD matrices, and extracting S_{21} throughout the entire frequency range.

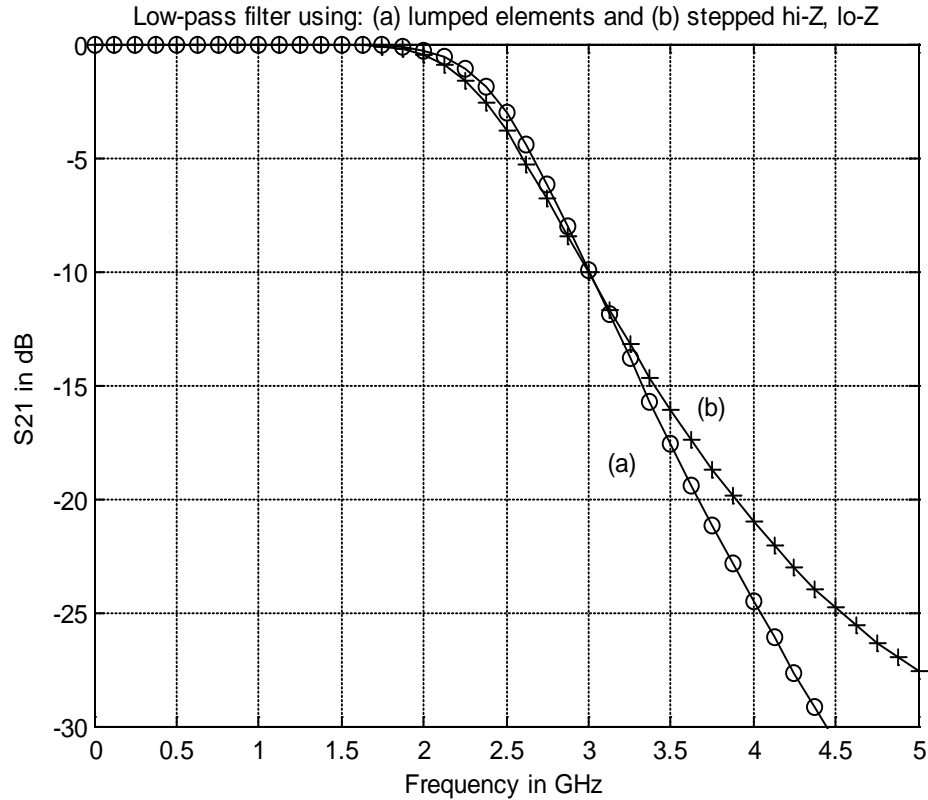


Fig.15. S_{21} in dB versus frequency in GHz for the low-pass filter implemented using: (a) lumped elements and (b) microstrip lines.

Fig. 15 shows how closely the microstrip device approximates the lumped-element performance, with each device giving performances close to the design specifications at 2.5 GHz and at 4.0 GHz. Beyond 3.5 to 4.0 GHz, the stepped-impedance performance starts to differ from the lumped-element ideal. Study of its performance beyond 6 MHz indicates that the microstrip version no longer provides a satisfactory approximation of the lumped-element filter for that higher frequency range. If suppressing frequency components in this range were necessary, additional filtering would have to be employed.

The stepped-impedance filter that was fabricated is shown in Fig. 16.

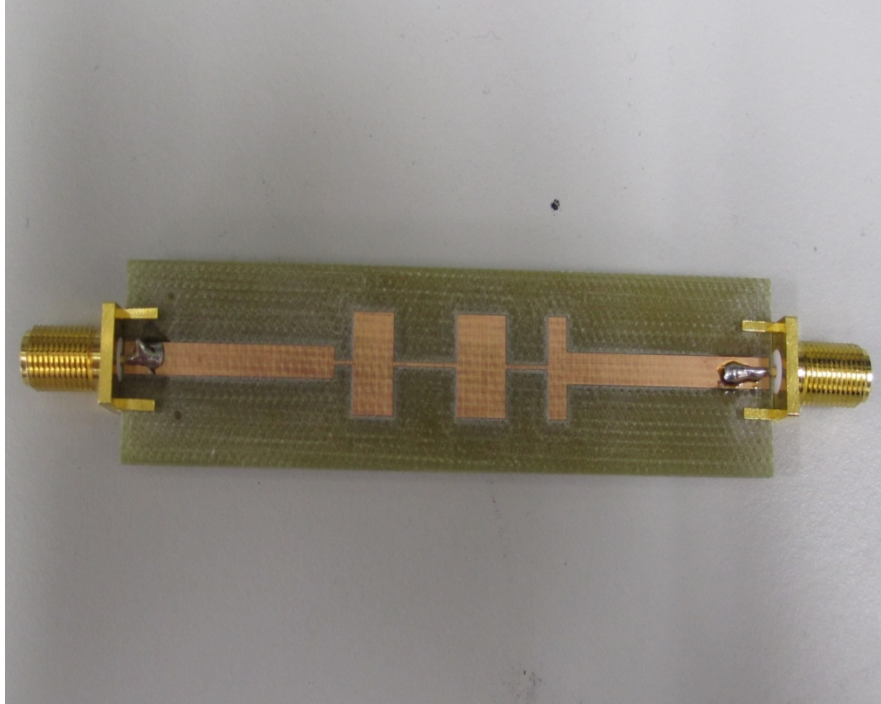


Fig. 16. Fabricated stepped-impedance filter.

The actual performance of the filter was obtained using an Agilent E5071C network analyzer. The response that was generated produced a result (Fig. 17) that had a cutoff frequency of 2.5 GHz and had more than a 20-dB insertion loss at 4 GHz. The response obtained with the fabricated device is consistent with that specified in Pozar.²

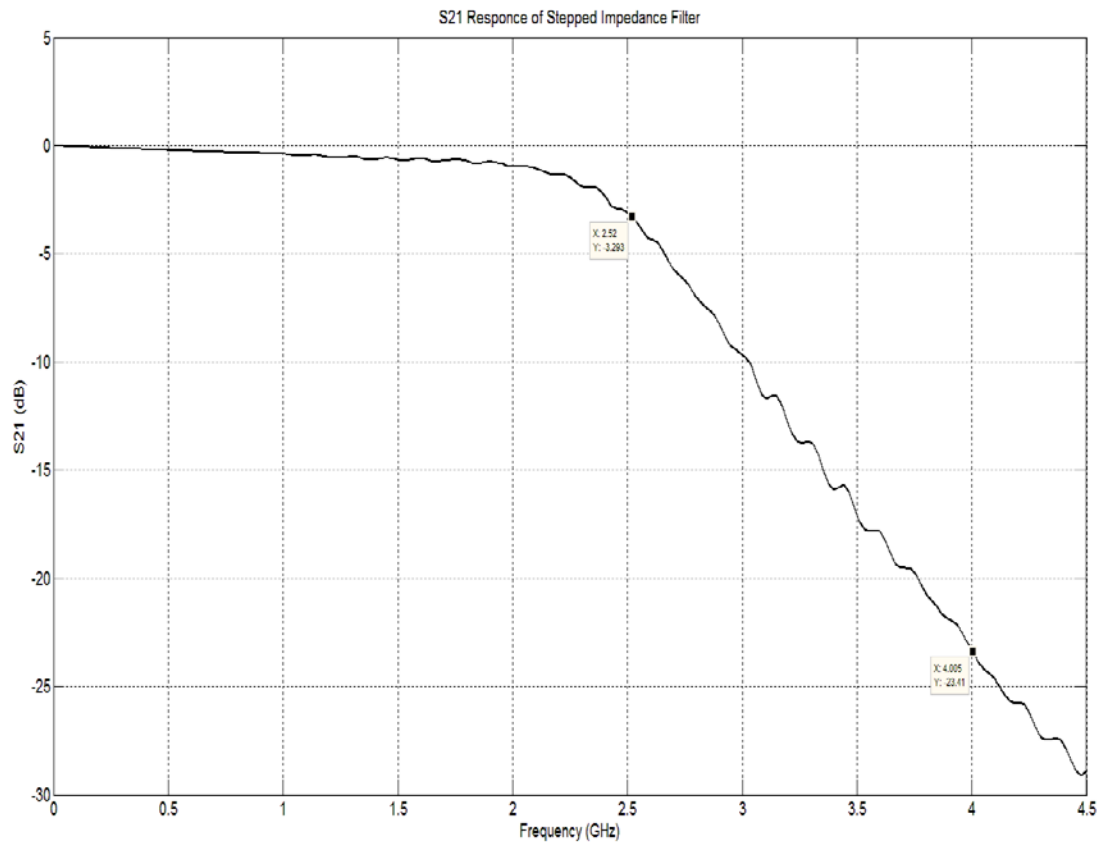


Fig. 17. S_{21} in dB vs. frequency in GHz for stepped-impedance filter using network analyzer.

Summary and Conclusions

In this paper the Computer-Aided Microwave Design System (CAMDS) as originally developed by Bais¹ and implemented and verified by Sharma³ was the central focus. A context for this paper was developed by reviewing the scattering parameters since they are of such great importance throughout the paper. This was followed by a review of the basic processes involved in using CAMDS. It was used to obtain a recommended design. Then, as an example, the CAMDS design results for microwave stepped-impedance filter were rigorously verified by comparison with results: (i) reported by Pozar, (ii) simulated by ADS, (iii) fabricated and tested using ADS layouts, and (iv) obtained by independent computer analysis.

The work reported here builds on the comprehensive original work of Bais (CAMDS). That work consisted of approximately 5,400 lines of computer code and dealt with a wide spectrum of devices including those designed not only in microstrip, but also in stripline and waveguide. The experiences reported in this paper will provide future users with increased benefits due to the demonstrations of reliability. CAMDS is an excellent design tool for microwave engineering education since it generates complete lists of parameters for a given specification and has

established a pattern or structure for future inclusion of transmission lines implemented in other technologies and for future inclusion of more advanced microwave devices.

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The Impact of Real World Engineering Problems on Student Motivation in Calculus

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Abstract

Calculus is one of the biggest academic obstacles to student persistence in engineering. New students in engineering are expected to take calculus at the beginning of the college curriculum, specifically in the first and second semesters, because calculus is positioned as a prerequisite for postsecondary study in engineering. For some students, taking calculus is a test of their endurance; requiring them to submit to a year of calculus instruction before allowing them to pursue their interest in engineering related problem-solving can be extremely demoralizing. As such, many students leave their intended engineering major before they have completed a single engineering course.

The objective of this work is to describe a project that shows students the strong link between calculus and engineering by having students use mathematical concepts from their calculus class to solve real-world engineering problems. This was accomplished by the creation of 32 stand-alone problems, distributed in modules, that provide all the engineering background needed to arrive at the solution. The modules focus on applications that demonstrate how engineers use their skills for societal benefit and they contain topics from a variety of engineering disciplines. Results of the project indicate that students enjoy solving the modules and that the modules are helpful in learning calculus. Students also provided feedback that their comfort and confidence levels in using calculus to solve engineering problems improved after working through the modules.

Introduction

Students who leave engineering in their first year most often cite calculus as a major factor in their decision^{1,2}. Engineering educators have been working to address this issue by augmenting calculus with engineering content. Several methods have been used to augment calculus with engineering content including: team-teaching calculus³, offering companion course(s) in engineering^{4,5}, and offering a specialized calculus course for engineers^{6,7}. Despite positive results, adoption has been slow because each method has significant costs and challenges associated with it. Team teaching is difficult to implement and often requires institutional and policy changes to properly compensate and recognize the efforts of the instructors. Companion course offerings run a risk of jeopardizing students' academic status, because poor academic performance in one course can affect student performance in the companion course. Poor performance in two or more courses will result in academic probation and/or loss of financial support.

The most commonly adopted solution is the creation of an engineering calculus course, i.e., calculus augmented with engineering content and taught by engineering faculty. The disadvantage of calculus taught by engineering faculty is that, unlike mathematics faculty who

take the holistic approach to teaching calculus, engineering faculty members tend to focus on specific engineering applications, often resulting in teaching a “watered-down” version of calculus that lacks attention to mathematical fundamentals. Students only learn certain concepts and their applications to a limited number of scenarios. They are not prepared to extrapolate when new scenarios are encountered, putting students at a disadvantage to compete with their domestic and international peers and limiting their potential to innovate.

The objective of this work is to describe a project that shows students the strong link between calculus and engineering by having students use mathematical concepts from their calculus class to solve real-world engineering problems. In the process, we sought to enhance the student experience in calculus without significant institutional cost or the loss of a general approach. The modifications were constructed in a way that encouraged students to spend more time applying and discussing calculus with their peers. This was accomplished through the creation of a set of modules that use real world engineering problems to illustrate the importance of calculus concepts. The modules were completed and discussed outside of class time; there were no changes to the calculus course content.

Methods

The full study began in the fall 2011 semester with students enrolled in Calculus I and continued in the spring 2012 semester with students enrolled in Calculus I and Calculus II. Students were informed of the opportunity to participate in the study through an announcement in the first week of Calculus I or Calculus II class. The announcement provided a brief description of the program and indicated that it was completely voluntary. Students who enrolled in the Calculus I and Calculus II courses but chose not to participate in the study were still invited to the mentor sessions so as to avoid bias or penalty for nonparticipation.

Students’ participation was encouraged through the offer of up to 5% extra credit in the calculus class in which they were enrolled. The students received the extra credit if they attempted at least seven of the modules and attended the corresponding discussions. The amount of extra credit was scaled down proportionally based on their participation. Students were allowed to leave the study at any time during the semester.

Additional description of the methods used in this study, specifically related to the module problems, mentor-led discussion groups, and data collection procedures are presented in subsequent sub-sections.

Modules

The modules were constructed to encourage students to practice the application of calculus to real-world engineering problems. Two sets of eight modules were created: one set for Calculus I and another for Calculus II. The modules were distributed on a biweekly basis throughout the semester. Each module contained two real world engineering problems followed by set of

questions that guide students to the solution. The modules were written with the assumption that students did not have an engineering background. In other words, only calculus skills and knowledge were required to solve the module problems. An example module can be found in Figure 1.

The structure of each problem is similar to the “Flood Control” problem that is displayed in Figure 1. The problem begins with a description explaining the real world problem, with effort to craft the description in a way that illustrates the direct and immediate effects that engineers can have on society. To highlight the real world nature of the problem, images depicting parts of the problem are provided. In this case, students are shown a picture of a reservoir. In addition, the description presents any information needed to solve the problem. This is followed by the questions which guide students through the step-by-step process needed to solve the problem using calculus concepts presented in class. The problem ends with a question asking them to make an engineering decision or to discuss the impact of their findings.

The engineering concepts as the subjects of the problems were specifically selected to have broad appeal. The majority focus on problems from medical applications, charitable engineering projects, renewable energy, and unmanned aerial vehicles. In addition, the problems were used to illustrate the importance of engineers to society.

The full sets of modules with solutions are available upon request. To view additional sample modules and to get additional information please go to <http://engineering.und.edu/calculate>.

Mentor-led Discussion Groups

Students in the study were organized into small mentor-led discussion groups to work on the module problems. Groups were constructed using the Comprehensive Assessment for Team-Member Effectiveness (CATME) Team-maker tool, developed and maintained with support from the National Science Foundation⁸. The CATME system gathered information on student schedules, major, gender and race/ethnicity, based on student responses to an online questionnaire. The system then formed groups based on the collected information, and on available times to meet. In addition, the program attempted to place students in such a way that those from underrepresented groups were never outnumbered.

There were eight modules and corresponding mentor-led discussion sessions, spaced evenly throughout the semester. Each group session lasted approximately one to one and a half hours; no session exceeded two hours. Students met with mentors to discuss their solutions after having approximately five days to complete them. During the mentor-led discussion groups, participating students took turns presenting solutions to the module problems. When not presenting, students were encouraged to engage in discussion and reflection on the problems as well as the solutions. Students were expected to attend a minimum of five mentoring sessions.

Flood Control

Due to high water levels in the fall, recent rains and snow melt the dam on a local reservoir, shown in Fig. 1, is in danger of being topped. Last year under similar conditions the rise of the reservoir was tracked. The data is shown in the plot in Fig. 2. This data can be represented with the polynomial

$$d = -7.15 * 10^{-9}t^3 + 1.15 * 10^{-5}t^2 + 1.85 * 10^{-3}t + 50$$

where the water level, d , is a function of time, t . The water level in the reservoir is in feet, while the time is specified in hours.

1. Use the polynomial above to fill in the table below.

Time [hr]	Reservoir Level [ft]
0	
200	
400	
600	
800	
1000	

2. Using the table above calculate the average flow rate for the intervals: $[0, 200]$, $[200, 400]$, $[400, 600]$, and $[600, 800]$.
3. Draw a tangent line on the graph at a point on the interval with the maximum average reservoir level increase per hour. Estimate the slope of the line.
4. The flood gates need to be opened to prevent any further rise in the reservoir and the dam being topped. The amount of water released needs to be limited to prevent downstream flooding. Using maximum rate of reservoir increase determine the release rate required to guarantee no further rise in the reservoir. Assume that the surface area of the reservoir is fixed at $3 * 10^8 \text{ ft}^2$. The inflow rate is given as

$$\text{flow rate} = \text{reservoir rise} * \text{surface area}.$$

What should the desired outflow rate be?



Fig. 1: The dam that high water levels are threatening. Water must be released to ensure the dam does not fail

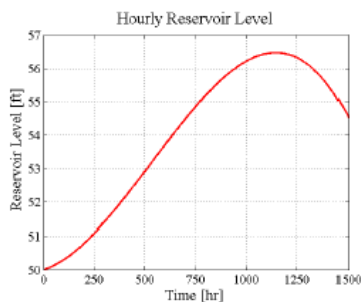


Fig. 2: Level of the reservoir over the course of last year's spring.

Figure 1: One of the Calculus I problems. Two such problems were included in each module.

The development of the mentor-led discussion groups was based on an educational model employed at Cambridge University in the United Kingdom. In this model, students are given problem sets to complete. The students meet with “supervisors,” typically a graduate student, in groups of four to five students. The supervisor asks each student to present a portion of their solution to the problem set. As they progress through the problem set the supervisor facilitates discussion on important points and guides the students to the correct solution when they have errors. Students are not graded on the correctness of the solution they provide, but rather on their level of participation.

In this work, the Cambridge model is used to deliver the modules. Students meet in groups of three to four to discuss the modules. It is important to note that like the Cambridge model, student performance is only measured by their level of participation. This provides students with an opportunity for no-risk, real time feedback. Such opportunities are not common in the American system where students traditionally turn in assignments, are penalized for errors, and receive the feedback asynchronously days or weeks later. Providing immediate, interactive process feedback decoupled from personal feedback such as grades is one of the most effective ways to use feedback to facilitate student learning^{9,10}.

Unlike the Cambridge model, the discussions are led by a diverse group of undergraduate mentors. This is an important difference. Using peer mentors has been shown to be effective in increasing student persistence¹¹. In addition, undergraduate mentors have recently negotiated the same obstacle that student participants are currently facing. This allows mentors to provide unique insights that faculty and graduate students cannot. Additionally, the undergraduate student mentors provided the student participants with links to engineering students groups such as the SAE car team and IEEE student chapter. These activities are important for student persistence¹². Such connections help student persist through academically difficult times.

Data Collection

Participants in the study were asked to provide feedback on their experiences on two occasions: once at the midpoint of the semester by completing the Calculus Knowledge and Perspectives (CKP) survey and again at the end of the semester by completing the Modules and Mentors (MM) survey. Both instruments were reviewed and approved by the Institutional Review Board (IRB) at the University where it was administered. Upon certification that the study and the instruments met the human research subject protections and obligations as required by law and University policy, the first instrument, the Calculus Knowledge and Perspectives (CKP) survey, was administered via paper copy during the week when the first student/mentor meetings took place (n=89). The second instrument, the Modules and Mentors (MM) survey, was administered during the last week of student/mentor meetings (n=51). This instrument was similar to the CKP survey, with questions added to gather feedback on the discussion groups and modules. The initial MM data collection in fall 2011 was completed using an online version of the survey. The

survey was administered via paper copy during the student/mentor meetings in spring 2012. The paper based surveys improved the student response rate significantly.

Both instruments are available upon request. Additional information on the surveys can be found at <http://engineering.und.edu/calculute>.

Results

One of the objectives of this work is to provide students an opportunity to apply calculus knowledge. Anecdotal observations of students indicate that students often resist doing problems because they are boring and dry. The modules intend to provide a more palatable alternative to traditional textbook problems. Student perceptions of the modules were measured by asking students about each problem (see Table 1 and Table 2). Responses indicate that students overall were indifferent to or liked (preferred) the problem. In fact, no problem received more than 18% of the students indicating that they “did not prefer” it and the average “did not prefer” rate was less than 10%. Almost half of the models (14 of 32) had 40% or more of the students indicating that they “preferred” the module. Of these modules, seven enjoy an “preferred” rate of 50% or more.

Table 1: Module problem preference among calculus I students.

Module Topic	Did not prefer % (n)	Neutral % (n)	Preferred % (n)
Flood control	3.6(1)	50.0(14)	46.4(13)
Plastic production (making chairs)	7.1(2)	71.4(20)	21.4(6)
Shuttle arm motion	7.1(2)	46.4(13)	46.4(13)
Wind turbine: Angle of attack	3.6(1)	46.4(13)	50.0(14)
The Haitian crisis (clean drinking water)	7.1(2)	57.1(16)	35.7(10)
Saturn V rocket acceleration	3.6(1)	35.7(10)	60.7(17)
Low orbit satellites	7.1(2)	35.7(10)	57.1(16)
Diffusion bonding	17.9(5)	53.6(15)	28.6(8)
DARPA challenge and autonomous vehicles	7.1(2)	46.4(13)	46.4(14)
Electromagnets	14.3(4)	53.6(15)	32.1(9)
Gel electrophoresis image analysis	14.3(4)	53.6(15)	32.1(9)
Portable devices: Resistors	7.1(2)	64.3(18)	28.6(8)
Diabetes and foot ulcers	17.9(5)	53.6(15)	25.0(7)
Green energy: Greenhouse gas emissions	0.0(0)	50.0(14)	50.0(14)
Wind energy	3.6(1)	53.6(15)	39.3(11)
Aircraft and rivets	17.9(5)	35.7(10)	46.4(13)

Table 2: Module problem preference among calculus II students.

Module Topic	Did not prefer % (n)	Neutral % (n)	Preferred % (n)
Aircraft and rivets	17.9(5)	35.7(10)	46.4(13)
Tumor growth	13.0(3)	65.2(15)	21.7(5)
Aircraft systems composites	0.0(0)	47.7(11)	52.2(12)
Pacemakers	4.3(1)	69.6(16)	26.1(6)
Renewable power investment	0.0(0)	60.9(14)	39.1(9)
Prosthetic arm	13.0(3)	60.9(14)	26.1(6)
Wind turbines	0.0(0)	47.8(11)	52.2(12)
Collision avoidance and smart vehicles	0.0(0)	65.2(15)	34.8(8)
Water for Malawi	8.7(2)	56.5(13)	34.8(8)
River flooding	13.0(3)	56.5(13)	30.4(7)
Unmanned aerial vehicles (UAVs)	4.3(1)	39.1(9)	56.5(13)
Robots for rehabilitation	4.3(1)	52.2(12)	43.5(10)
UAV parameterization	4.3(1)	52.2(12)	43.5(10)
Microscope design	0.0(0)	69.6(16)	30.4(7)
Collision avoidance model	8.7(2)	65.2(15)	26.1(6)

The modules and discussion sessions were also successful in getting students to apply and discuss calculus outside of class. Eighty five percent of the students who attended the study sessions completed the modules. Moreover, the average attendance rate for participants was 82%. This was extremely high, considering that students only needed to attend 88% of the sessions to receive full credit—students were allowed to miss one of the eight sessions without being penalized.

Participants were surveyed in the beginning of the programs and again at its conclusion. They were asked on both surveys to indicate their level of confidence in their calculus abilities. After completing the program, 82% of the participants indicated they were confident, very confident, or extremely confident in their mathematical abilities an increase 6% over the initial results. Moreover, the percentage of students indicating that they were “not at all confident” with their abilities was reduced by 41%.

Students indicated that the modules were “helpful” (35.7%) or very helpful (25.0%) in increasing their understanding of calculus. Moreover, students also felt that working with peer mentors was “helpful” (35.7%) or “very helpful” (25.0%). Additionally, participation required students to dedicate a portion of their day to practicing and discussing calculus. This is important because it has been found that supervising student study sessions can have a positive effect on student success¹³.

The program also helped students feel more connected to engineering. There was a 67% decline in the percentage of students that did not feel any connection to engineering from the beginning of the program. Unfortunately, only 7% of the participants indicated that they felt very or

extremely connected to engineering after the program. This number was unchanged from the beginning of the program.

Discussion

Our original objective was to present a low cost method requiring minimal institutional change to improve the calculus experience for students. The method presented allows unmodified calculus courses to be augmented with engineering content. The benefits of the program are evidenced by the improvement of students self-efficacy. Research has shown that it is not necessarily students' real abilities, but rather perceived abilities, that lead to them switching away from engineering as an academic major¹⁴.

Students also indicated that they felt the program prepared them for success in calculus. This was shown by the fact that participants overwhelmingly indicated that the mentor, student interaction, and completing the modules were beneficial. At minimum the program got students to apply and discuss calculus concepts outside of class. Such activities are important to student success and lead to deeper learning. Moreover, motivating students to apply calculus concepts to real-world engineering problems has helped students better understand the importance of calculus to engineers. It is hoped that by re-enforcing this belief student will be more likely to invest the time needed "learn" calculus rather than just pass it.

Conclusions

The results show that the modules are a powerful teaching tool that can be used to get students to apply and discuss calculus with their peers outside of class time. The modules can be used concomitant with an existing course and require minimal institutional change to implement. The only cost related to implementing the modules is incurred by hiring the peer mentors. This cost is similar to that of hiring calculus tutors; a service already provided at most institutions.

One area that the program fell short in was connecting students to engineering. While participation did help those students that felt no connection to engineering, there was little effect on the other students. This issue will be addressed by working with mentors to emphasize the need to connect students to enrichment activities in engineering. It is hoped that this emphasis will lead to the program having a greater effect in this area.

Acknowledgements

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The Impact of Study Abroad on Students and Hosting Companies

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Abstract

In light of today's global marketplace the University of Wisconsin Stout has been pushing to create more global opportunities for their students. Knowing the value of study abroad from firsthand experience the author created and led a course in May of 2012 titled "Packaging in Germany". The program was a joint effort between the University of Wisconsin Stout and the German trade organization, Packaging Valley Germany, located in Schwabisch Hall Germany. This ten day active learning program involved cultural activities and plant tours. The paper will review the specific objectives and outcomes of the course from the perspective of the university, professor, students, and hosts.

General University Study Abroad Overview

A lot of research has been done in the area of study abroad and much of it shows very positive implications for the students. Indiana University found that students that participated in study abroad programs earned higher grades and graduated quicker than students not participating in such programs¹. St. Mary's College in Notre Dame, Indiana found similar results when it researched the relationship between students who studied abroad and their non participating peers. Approximately 90% of the study abroad students tracked graduated in 4 years compared to only 80% for students that did not study abroad². The University of Delaware studied the outcomes of short-term study abroad programs and found among all groups of students participating in a study abroad program, at least 80% reported growth in independence, cultural sophistication, awareness of international issues, overall maturity, self confidence, and adaptability³.

The University of Wisconsin Stout (Stout) also recognizes the benefits of study abroad. Their goal for its FOCUS 2015 Strategic Plan is to "Develop knowledge, respect and validation of differing values, cultures and beliefs in students, faculty and staff"⁴. The University of Wisconsin Stout Office of International Education currently has about 250-300 students studying abroad each year. Programs offered range from short faculty led programs to a full academic year. They also noted a recent trend with Stout students opting for short term, faculty led programs instead of the more traditional semester or full year program.

Packaging in Germany Program Inception

Until the inception of the Packaging in Germany program, Stout did not have any specific study abroad opportunities focused on its "Packaging" Bachelor degree program. In late spring of 2011 the author, Robert Meisner, was in Dusseldorf, Germany attending Interpack, one of the largest trade shows in the world focused on the packaging industry. While there he found himself reflecting on his positive study abroad experience with Michigan State University's School of Packaging in 1992.

The Michigan State University program took place in London over the course of several weeks in the summer and focused on packaging. Wanting to offer a similar experience to current Stout Packaging students he started to gauge company interest for creating a shared experience between German companies focused on packaging and American packaging students. While inquiring with many companies over several days Meisner eventually was directed to the trade organization “Packaging Valley Germany” A general interest was established and discussions continued for several months after the show ended. An outline of desired outcomes and responsibilities were agreed upon between Meisner and the Packaging Valley Germany organization in August, 2011 and work began to gain Stout support. A program proposal was written and submitted to the university administration for approval. Given Stouts vision to have collaborative programs that integrate applied learning, theory and research with business, education, industry, arts and government⁵ the new program was justifiable and approved with overwhelming support from the university.

Program Implementation

By late October 2011, less than five months after the program inception, the faculty led study abroad program became official and was scheduled to begin in the summer of 2012. The process of implementing the program involved defining the key objectives for the students and German partners, and working with the Stouts Office of International Education to create and publish a promotional flyer outlining the program. Work continued between the program professor and Office of International Education to plan and finalize the dates and begin making the plans for lodging, group activities, local transportation and other budget items. Promotion of the program and recruitment continued for the remainder of the fall 2011 semester and into the spring of 2012. Program posters were printed and distributed and other engineering and technology faculty members were asked to help promote the program by announcing it in their classes.

Another very effective method of promotion was to make the student packaging organization aware of the program and benefits. This was accomplished by announcing the program in their weekly meetings and inviting a guest speaker from one of the German host companies. The guest speaker was very positive and energized when discussing what the students would experience if they enrolled in the Packaging in Germany program. Feedback from the nine students that attended the inaugural summer 2012 program overwhelming stated the guest speaker from the German helped them finalize their decision to attend.

Objectives

The university, professor, students, and German hosts all had unique objectives that had to be met for the program to be considered a success. These were clearly defined as part of the program proposal process.

University objectives

- Enhance global learning opportunities
- Create new course offerings
- Increase visibility in the global marketplace

Professor objectives

- Give packaging students an opportunity to experience world travel
- Increase students appreciation and understanding of cultural differences
- Grow students technical packaging knowledge
- Create an opportunity for students to grow their personal networks

Student objectives

- Gain new packaging knowledge
- Improve personal growth
- Experience international travel
- Go to Germany

Host objectives

- Increase their visibility in the global marketplace
- Increase product awareness
- Drive demand for their products and services
- Establish USA University relationships
- Promote their country and technology

Outcomes

University outcomes

By approving and helping facilitate the Packaging in Germany program the university met all of its goals. They enhanced global learning opportunities for the Packaging students and increased their visibility in the global marketplace in several ways. The Packaging Valley Germany member companies now have a deeper understanding of Stouts Packaging program and the Universities role in supporting Packaging education. This was accomplished via plant tours, the association with Packaging Valley Germany and the press that resulted from the program. Internationally the local German press attended two of the three days of plant tours. They talked with students and hosting companies and took a lot of photographs, some of which were included in their newspaper articles following the tours. Domestically the program was profiled in one of the largest Packaging trade journals, Packaging Digest.

Professor outcomes

The students were required to complete a detailed survey upon their return as part of the program requirements. This was the professors way of evaluating the outcomes and document the experience. The results of the survey were shared with Packaging Valley Germany and the Stout Office of International Education

The program was wildly successful at meeting the programs goals established for the students. The students returned having experienced world travel. They had an increased understanding of some cultural differences between Germany and the USA and the student's technical packaging knowledge and personal networks grew as a result of the program.

Students were asked to grade how well the program fulfilled its objectives. The anonymous student responses were tallied and averaged. The results are as follows and are based on a 4.0 grade scale.

- Increased knowledge and understanding of German culture – 3.96
- Increased knowledge of German packaging and packaging industry – 3.77
- Expand personal growth in areas of technical knowledge and personal networks – 3.69

Student outcomes

Students had a variety of reasons for attending the program. The most common reasons students attended were to learn more about packaging machinery, German culture, experience study abroad and have a foreign experience to add to their background. When asked how well the program met their own personal goals the student overwhelmingly agreed their own personal goals and objectives were met. Some of the comments from the anonymous survey included:

- “My goals were met. I found the country to be beautiful and exciting to explore. I definitely learned a lot about various packaging machinery companies and enjoyed the students and professor who attended”.
- “My goals and objectives were not only met, but they were exceeded. I got to tour some amazing cities in Germany, I was immersed into the culture with some of my now closest friends, and I learned more than I ever could have imagined in regards to German packaging and machinery manufacturers”.
- “Yes I was very happy with the program. I learned a lot about machinery and have built contacts for the future. I experienced a different country and all that it had to offer with the train, different foods, living conditions, cultural norms, and much more. I also learned a bit more about German history, going to that art museum and seeing the castle were a big part of that”.

Host outcomes

Based on feedback from the tour hosting companies and Packaging Valley Germany organizers, the trip was a huge success. They had fun learning from and spending time with the students. They enjoyed sharing their culture and helping the students gain a deeper appreciating for the technology their country offers the world of packaging. They were also very proud of the fact the program was profiled in two of their local newspapers during the trip.

There were several questions included in the anonymous student survey designed to get specific feedback for Packaging Valley Germany and its members. They all had a vested interest in knowing participants perception so a determination could be made as to the value of the time and money they had invested in the Packaging in Germany program.

Students were asked to provide their overall impressions about the Packaging Valley Germany organization and the value they provide to their members. “Impressed” and “very positive” were common themes in all the responses.

Students were also asked to provide feedback specific to each of the companies toured regarding what they liked and why. All three of the companies received high praises for their time and providing a very unique learning opportunity for the students. Students particularly enjoyed being able to walk the factory floors and see machines being assembled and tested.

The final question the students had to answer regarding each of the tours was “As a result of the tour are you more likely to consider using (company name inserted here) services in the future over one of their competitors?” All of the students said yes and backed up their answers with positive attributes the company portrayed and products offered. This was the most enlightening question for Packaging Valley Germany and its members.

Conclusion

The program provided a positive experience and value to all those involved with the program. The Packaging in Germany program succeeded at meeting all the goals it set out to achieve. The university increased its study abroad offerings, created unique learning opportunities for its students and increased global awareness of its objectives and programs. The professor learned a lot about each student and the host companies which will aid in improving and growing the program in future years. The organization, Packaging Valley Germany, was also very pleased with the results and found tremendous value in participating. So much so that they have offered to help host the program again in 2013. It is the authors opinion the fact that all of the students stated they would specify and recommend Packaging Valley Germany member companies products and services as a result of their experience as the single biggest reason the Packaging in Germany program will continue into the future. Without the support of Packaging Valley Germany, the program would be too difficult to plan and be cost prohibitive for students. The feedback from the students that attended has been nothing but positive. Upon their return the students have been sharing their experiences with other students, generated a tremendous amount of inquires and demand for the program.

Future goals will continue to evolve as the program grows. Packaging Valley Germany members have expressed in interest in creating a cooperative education program to give Stout students and opportunity to participate in an internship working at their companies. The professor has also been in discussions with Packaging Valley Germany to include tours of packaging material manufacturers and convertors and possibly increasing the number of days spent in Germany as a way to broaden the scope and value of the program for the students.

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Technical and Pedagogical Issues with Embedded System Engineering Education

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Abstract

Embedded system technology exists in numerous high tech products used in daily life today. Embedded system engineers are in big demand in industry. However, the technology and hence the skills and knowledge used by embedded system engineers change enormously and continuously. Therefore, the curriculum and the courses of computer engineering programs should be designed and permitted to evolve with feedback from industry to keep course content meaningful and up to date. Another important issue related to embedded systems engineering is to assure that effective teaching methods are used and good student outcomes are obtained during the delivery of education to the next generation of embedded systems engineers. In this paper, experiences related to these issues in Computer Engineering program at University of Wisconsin – Stout is presented and some future trends are discussed.

1. Introduction

An embedded system is viewed as any object that contains a computing device (e.g. a microprocessor, microcontroller, or a digital signal processor) with the object itself not functioning as a general purpose computer. Products that contain embedded systems prevail all people's lives with smart phones, navigators, digital cameras, routers for computers, game consoles, medical devices, and many others. Development of these numerous devices increases the demand for embedded system engineers by industry globally. However, the skills and knowledge required by the embedded systems community is continuously changing¹⁻⁴. The computer engineering programs should be designed and permitted to change from time to time with feedback from industry. This is essential to keep the program content meaningful and up to date.

A significant number of papers have been published recently on embedded systems engineering education. Included are papers related to contents of embedded systems courses, curriculums of the programs, and pedagogies used in teaching. A few papers are on new programs and courses emphasizing applications using different platforms or technologies⁵⁻⁸. There are programs which train students mainly as software programmers or hardware engineers^{5,6,9,10}. B. Haberman and M. Trakhtenbrot reported commencement of a new program for a B. Sc. Degree in Embedded Systems Engineering at Holon Academic Institute of Technology in 2005¹¹. There has been a

strong interest in the academic world in developing teaching methods that make students more active and more engaged for most discipline¹²⁻¹⁶.

In this paper, the University of Wisconsin computer engineering curriculum is presented as a new program to train embedded system engineers. Contents of main courses and some pedagogical issues are reviewed. What else can be done to keep an active learning environment and a content relevant to current technology is discussed.

2. Embedded Systems Engineering Education – University of Wisconsin - Stout Approach

The computer engineering program at University of Wisconsin - Stout started in 2008. The program is an excellent blend of software engineering and electrical engineering. Embedded systems engineering is a key component of the Computer Engineering program at University of Wisconsin – Stout. In this program, an embedded system is viewed as any object that contains a computing device (e.g. a microprocessor, microcontroller, or a digital signal processor) with the object itself not functioning as a general purpose computer. This definition allows us to consider any object from a simple appliance (like a digital watch) to complex portable integrated devices such as medical instrumentation and 4G cellular devices (each containing gigabytes of memory and a complex operating system) supporting a variety of embedded applications. Students are encouraged to engage their imaginations and engineering skills to solve real-life problems using embedded systems technologies (hardware and software) as well as the knowledge they gained from other coursework leading up to the embedded systems course¹⁷⁻¹⁸.

2.1. The curriculum

The curriculum includes courses on i) fundamentals of electrical engineering, ii) computer science, iii) automatic control and mechanical engineering, iv) digital logic, microprocessors, and embedded systems, v) senior design.

In fundamentals of electrical engineering courses, students learn electric circuits, electronics, signal analysis and electromagnetic topics and hence develop a strong electrical engineering foundation. They learn theories at a level appropriate with study level. They perform experiments in labs using real instruments, tools and components as well as using simulation programs like Multisim, PSpice, MATLAB and SIMULINK. Students take at least 7 computer science (CS) courses on computer programming, data structures, computer organization, computer architecture, and systems programming.

CEE 335 Automatic Control Systems covers classical methods of analysis and design for continuous-time and discrete time control systems. The introduction of continuous-time systems start with Laplace transform techniques for solving differential equations, modeling of dynamic systems in time and frequency domains, root-locus and stability analysis. The control

applications include controller design and programming for embedded-servo control systems and PC-based data acquisition in controls. The course prepares students to master control theory and have a good understanding of solving contemporary control problems through a problem based learning environment. The problem based learning allows students to develop skills that include modeling, control design, simulation, implementations, commissioning, tuning, and operating a control system¹⁹⁻²⁰. These skills are becoming more important as control hardware rely heavily on digital processors to achieve optimum controls. In order to enhance students' problem-solving skills, the Faculty at the University of Wisconsin built and purchased the control parts and trainers for students in controls and motion control laboratory.

I. Continuous-time control systems

The continuous-time control systems are taught with a strong emphasis on hands-on learning experience for students. The focus is on motion controls applications, so the Quanser Engineering Trainers (QET) is chosen and used extensively in our lab to teach continuous-time controls discussed in most control textbooks. The laboratory activities begin with a first-order modeling of a dc motor involving with its electrical and mechanical parameters. The advanced labs are to implement a Proportional-Integral controller (PI), a Proportional-Derivative (PD), or a PID controller on the trainers to achieve a desired angular speed and position controls.

II. Data acquisition systems

Most industrial control systems require data acquisition to monitor a process. LabVIEW and data acquisition hardware (USB-6351 X-series) have been used as a part of laboratory experience. The focus of data acquisition is to demonstrate how an electrical signal can be sampled and acquired without a signal aliasing. Industrial sensors such as inductive, capacitive, and photoelectric switches are used. How to output a signal to control an external periphery is also covered. The laboratory activities also include a digital control of stepper motor with a LabVIEW program and the data acquisition hardware.

III. Discrete-time control systems

Discrete-time control systems using Programmable Logic Controllers (PLCs) and industrial sensors play a major role in manufacturing processes and motor controls. Our control system lab utilizes Allen-Bradley PLCs, two-axis AC servo drives and motors to teach motion controls of X-Y Table. The complete system supports ladder logic programming and tuning for the servo drives and motor assembly to achieve a desired time and frequency response. Students learn the controller tuning techniques at the first part of the control course will find no difficulty in tuning the AC servo motors on PLCs. The wiring diagram and photos for the complete motion control system is shown below.

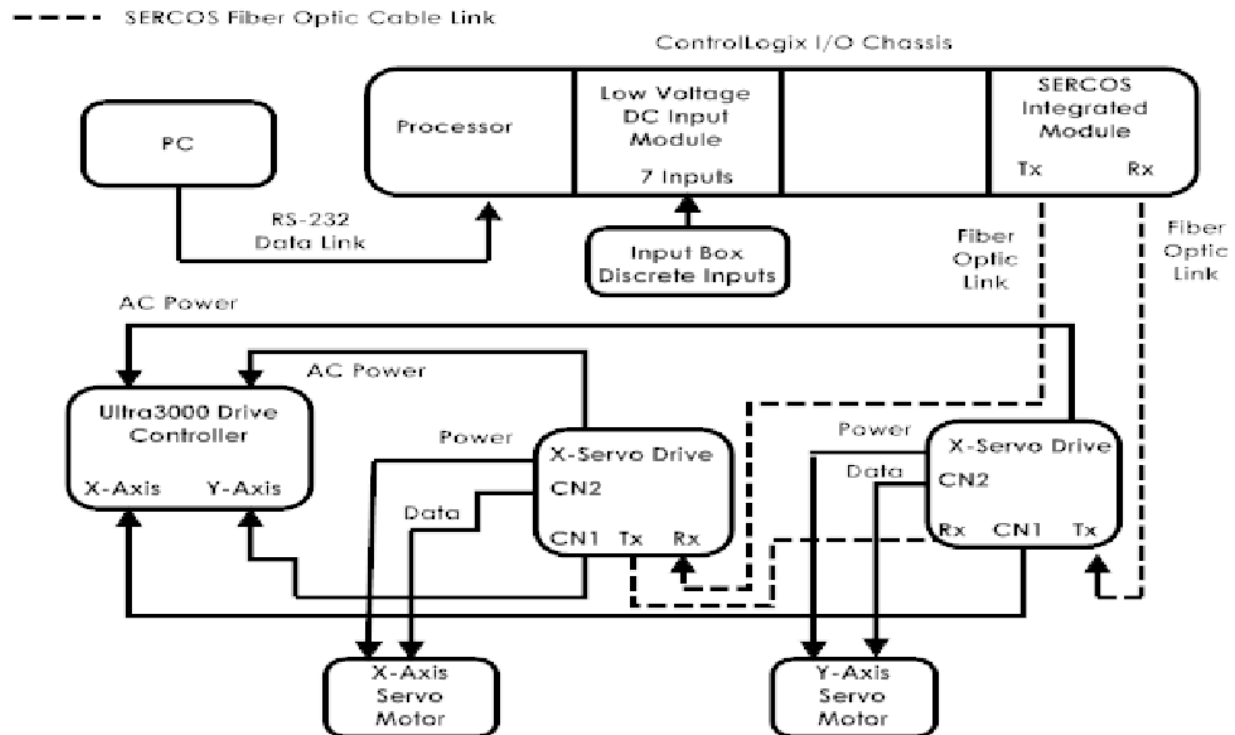


Fig. 1a Wiring diagram of the X-Y table with a Allen-Bradley PLC, servo drivers and motors



Fig. 1b Control panel and servo drives

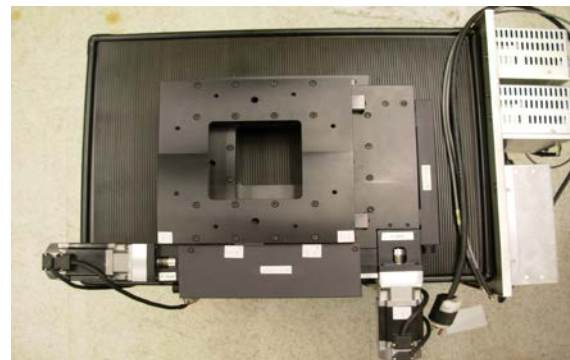


Fig. 1c X-Y table with two-axis servo motors



Fig. 1d PC and Allen Bradley PLC

Ladder Logic Programming for PLCs:

The ladder logic is a popular programming language for most PLCs. A simple technique is used to teach students PLC programming without prior experience in programming. A structured state transition diagram is a state machine, a flow chart to aid students to write a successful ladder logic program. The concept of a state machine and its state transition condition is covered in most digital logic textbooks. An example of complete state transition diagram and its ladder logic diagram for an X-Y table experiment is shown in the attachment with this paper.

MECH 293 Engineering Mechanics, MECH294 Mechanics of Materials and MFGE 275 Thermodynamics and Heat Transfer equip students with knowledge and skills in designing embedded systems as parts of mechanical systems. The last two groups of courses are directly related to embedded systems engineering and explained in details in the following:

2.1.1. Digital Logic, Microprocessors, and Embedded System Courses:

The course, CEE 225 (Digital Logic) includes electronics applications with standard and programmable chips on a digital logic experiment setup using scopes, meters, wires, logic analyzers, and other tools. Students also perform experiments and design work using digital circuit simulation software packages that include analog and logic components. Students also use Xilinx ISE FPGA design software to make more complicated advanced level design and verification with Verilog; a hardware design language standardized by the Institute of Electrical and Electronic Engineers as IEEE Standard 1364 in 1995. The students are encouraged to explore and experience software packages and programming languages not covered in the coursework such as Altera Quartus logic design software and the VHDL language.

In the course CEE 325 (Digital System Design), students learn how to design digital systems using off-the shelf components and Field Programmable Gate Array (FPGA) devices. They learn to synthesize digital systems behavioral and structural models using modern engineering design and synthesis tools. They also apply FPGA-based techniques to design microcomputer components like Arithmetic and logic (ALU) units, static random access memory (SRAM) design using register files, and data path controller design for RISC CPU (Reduced Set Computer). Using Verilog HDL in the Xilinx's testbench fixture, and running ISE simulator for timing and functional verifications to test the above mentioned design is emphasized throughout the course.

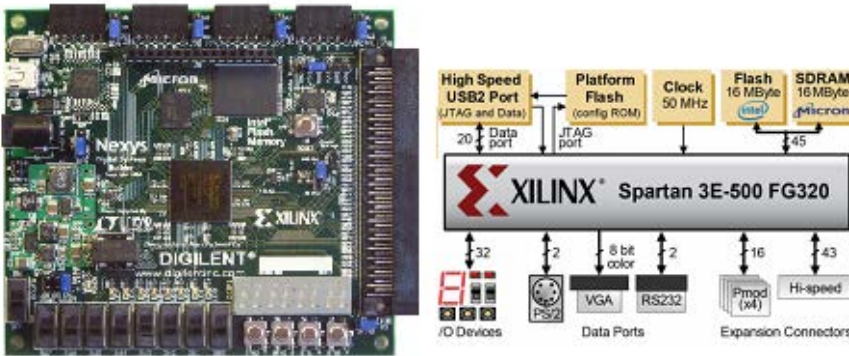


Figure 1: Xilinx's Digilent Training Board with Spartan3-200 FT256 FPGA (<http://www.digilentinc.com/Products/Detail.cfm?Prod=NEXYS2&Nav1=Products&Nav2=Programmable>)

The students are exposed to the Xilinx's Digilent Training Board with Spartan3-200 FT256 FPGA (Figure 1) and Genesis Virtex-5 FPGA (Figure 2). The Digilent-training boards are powerful digital system design platforms. The NEXYS-2 is built around a Xilinx -FPGA incorporating 500K programmable gates. With 16Mbytes of fast SDRAM and 16Mbytes of Flash ROM, on-board high-speed USB2 port, together with a collection of I/O devices, data ports, and expansion connectors, students experience a wide range of digital design experience using modern day digital integration and tools¹⁹. The Genesis board is built with Virtex-5 FPGA that allows students to implement Xilinx's soft core processors and design high speed ethernet applications , high-speed memory systems, audio and video compression and decompression hardware for digital TV or digital camera with video streaming capability.

The course CEE 345 (Microprocessor System Design) covers the internal organization of microprocessors, instruction sets, timers and interrupts, and serial and parallel ports programming using Assembly and C languages. The course teaches students contemporary issues involving microprocessors and microcontrollers in terms of cost, performance and applications. Students learn how to analyze engineering problems and propose solutions with competent use of microprocessors and interfacing peripherals. They also use emulation software for the design, analysis and performance verification for microprocessor system designs. The design platform of CEE-345 is the ATMEL STK-600 board that includes socket cards and routing cards for programming on most 8-bit MegaAVR, 8/16-bit Xmega, and 32-bit AVR UC3 microcontrollers. The STK-600 board has a USB interface to PC for programming microcontrollers in three selectable modes: serial in system programming (ISP) PDI, and JTAG. The coding and debugging interface to the AVR microcontrollers are available through the AVR studio 4 or later. The AVR studio software and its tool chain/device drivers are free for all AVR users.



Figure 2: Genesys™ Virtex-5 FPGA Development

The STK-600 board allows students to design and implement Embedded processor systems using 8-bit, 16-bit, and 32-bit microcontrollers from the ATMEL. With STK-600 board, the topics in the course description can be demonstrated in laboratory experiments including basic input and output ports programming, 8-bit and 16-bit timers programming, hardware and software interrupts design, polling strategies, programming with PWM, and ADC. The peripheral devices including DC motor, Stepper and servo motors, 4x4 keypad, switches, push buttons, and LEDs, 2x16 character LCD, relay and optoisolator for motor can be interfaced with the STK-600 board running with a selected microcontroller. The controller technology for touch screen applications can also be interfaced with the STK-600 board. The experiment setup for the STK-600 with a LCD and a stepper motor are depicted in Figures 3- b and c.

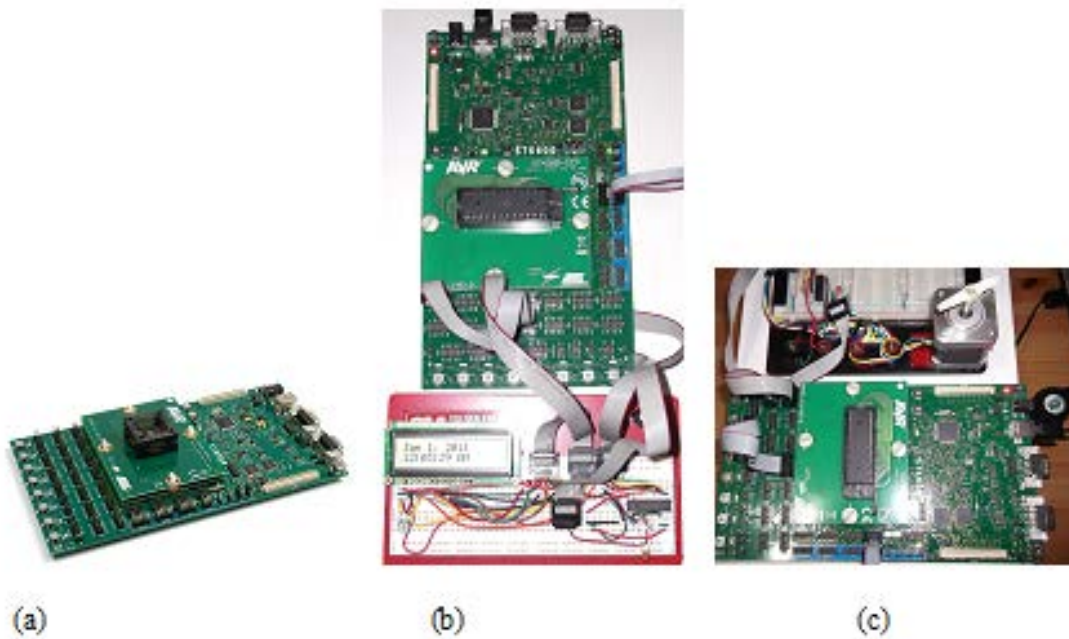


Figure 3: (a) STK-600 board (b) LCD interfacing (c) stepper motor interfacing

The course CEE 445 (Embedded Systems) covers a structured approach to the development and design of microprocessor, microcontroller, and mixed-signal embedded systems. Microprocessor types, memory structures, interrupt control, external interfacing, embedded sensing, and software will be emphasized including assemblers and higher level language support. Laboratory experiments support the design and implementation of an embedded system project. An important part of the course is a design project. Students do research on the assigned project topic, create a working model, and write a report on their experiences and findings. The project work is expected to reflect a serious effort to go beyond the course material, obtaining additional sources from the internet, journals, conferences, and/or books. Students learn to use the relevant languages, at least to the level of proficiency required to make their point. They get the compiler, simulator, design environment, and install it. The project is not evaluated on the basis of how much effort the students put into it, but rather on how effective the work is. The students can go to the internet or commercial software and hardware platforms and find something to build on. The foundation platform of CEE-445 is the Cypress PSoC 5 development kit. Cypress's CY8CKIT-050 PSoC® 5 Development Kit includes: 1. PSoC Creator, 2. PSoC Programmer (3.12.4 or later), and 3. Development board with Cypress' PSoC 5 (ARM CORTEX-M3 uP) [http://www.arm.com/files/pdf/IntroToCortex-M3.pdf]. The main features of the PSoC board are depicted in Figure 4.

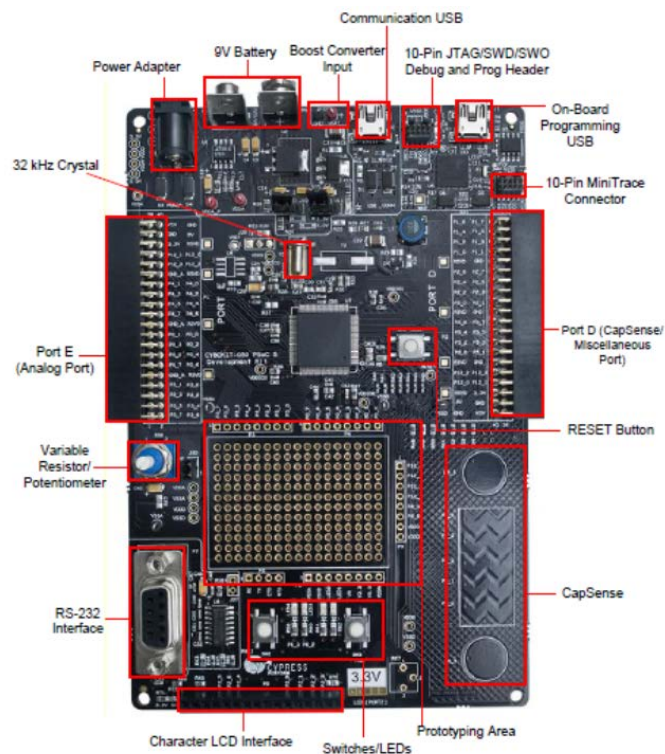


Figure 4: Cypress PSoC Development Board (<http://www.cypress.com/?rID=37581>)

The PSoC 5 development environment allows students to experience the design, simulation, and realization of mixed-signal engineering; a key factor in modern day product development. Embedded systems embody digital and analog realities. For example, the iPhone4 now includes: Ambient Light, Proximity Sensors, Dual Cameras, GPS, Accelerometer, Dual Microphones, Compass, and Gyroscope. It is anticipated that portable devices like the iPhone will include Personal Sensing, Health Sensing (e.g. blood pressure, heart rate, oxygen sensing, body temperature, etc.), and Environmental Sensing within the next few years²¹.

2.1.2. Senior Design Courses:

The objective of the sequence of the two courses, senior design I and II, is development of a strategic plan and the design of a product, process, and / or experiment(s) to solve an industry based or independent study problem related to computer and electrical engineering that requires research, problem solving, teamwork, communication skills, project management, documentation, simulation, experimentation and similar skills.

The first course, CEE 405 (Senior Design I) is research, conceptual design and simulation phase. The students apply previously acquired skills, knowledge, and experience doing the undergraduate study to practical applications encountered in an industrial environment. They utilize independent thought and research in developing problem solutions. They identify and design appropriate experimental or simulation methods. They are expected to demonstrate teamwork, leadership and project management skills by leading cross-functional teams, documenting outcomes, and providing timely status updates throughout the problem solving process. They defend the project outcomes achieved in both written and oral formats.

In CEE 410 (Senior Design II), students continue to work on a project whose conceptual design was completed in CEE 405. The students do implementation, prototyping, and testing of the design. They also prepare a compliance test plan and conduct the compliance test. They write a complete project report documenting the design, prototype, and testing. They present the project results to faculty and peers in a trade show setting. They students conduct all work with an understanding of professional and ethical responsibility. They are expected to manage time and resources for the successful completion of the project.

3. Pedagogical Issues in Embedded Systems Education

An important issue related to Embedded Systems Engineering is to assure that effective teaching methods are used and good student outcomes are obtained during the delivery of education to the next generation of embedded systems engineers. Clearly, the method should include active/engagement pedagogy not be limited to traditional pedagogies. The design of each course and the overall curriculum can be modified whenever necessary for this purpose. Students and professors are encouraged to use any on-campus and off-campus resources that will contribute to the student learning on the way to become an engineer. Undergraduate labs, research opportunities, the Center for Innovation and Development, the Discovery Center and the IEEE Student Branch are the some of on-campus resources contributing to the mission. How well the mission is supported is a good indication of the state of the program.

Active/engaging pedagogies aim to make students be active participants. This is accomplished with some creative methods during the teaching/learning process. The teacher's responsibility is not to impart the material but to be a facilitator of the learning experience^{13,15}. Scholarship of teaching and learning (SoTL) is the key way to obtain this assurance. Signature pedagogies are a SoTL method to train students to think like the disciplinary experts, i.e., embedded systems engineers in this case. SoTL asks more content- and learning-centered questions "what are we teaching, and "what are our students learning?". Good teaching means "good student outcomes". SoTL also asks "How can good student outcomes occur?", "Why?", and "When". These basic questions help us make teaching strategies evolve to obtain good student outcome¹³.

As it may be inferred from previous section, all the courses in the program have an applied study or lab component. The applications can be electronics experiments, simulations using software packages, designing, assembling and prototyping. The teaching and evaluation methods depend on the content and objectives of each course. Some options are problem-based learning, project-based learning, lectures and labs, and engineering design¹²⁻¹³. Closely related other methods include Cooperative Learning and Collaborative Learning. The professor is free to choose any of these choices or a smart combination of them to obtain what he or she thinks the most effective way to realize the course objectives.

The software and electronics boards used in digital, microprocessor, and digital signal processing, and embedded systems courses are evolving at a very fast rate. Those currently in use are reported in the course contents in the previous section. However, their versions change and even brand new ones come out very often. These are followed closely by the faculty and newer ones are implemented whenever necessary. This is critical.

Projects and design applications are more an absolute part of each course, especially senior courses. For example, as noted before in the paper, in CEE 445 students do research on the assigned project topic, create a working model, and write a report on their experiences and findings. The project work is expected to reflect a serious effort to go beyond the course material, obtaining additional sources from the internet, journals, conferences, and/or books. In senior design courses, students develop a strategic plan and the design of a product, process, and / or experiment(s) to solve an industry based or independent study problem related to computer and electrical engineering that requires research, problem solving, teamwork, communication skills, project management, documentation, simulation, experimentation and similar skills.

An essential part of the strategy to keep the program up to date is to have an active professional advisory board (PAB). The program has a strong advisory board. The members are from relevant industrial companies located in the region. The members have actively been involved in course, lab and curriculum development by providing excellent feedbacks. The companies represented by the PAB members are very enthusiastic to sponsoring senior design projects.

4. Results/Conclusions

The computer engineering program at University of Wisconsin - Stout is one choice for a student who wants to be an embedded systems engineer. There are programs similar to this and very different from this at other universities throughout the world. Keeping interaction with industry is a critical part of the management of the program. A supportive administration, excellent campus resources that support research, design, prototype development and collaboration are other important factors. A dynamic student branch of IEEE is also making big difference in the education. It gives a chance to students to understand and appreciate the profession they choose. It helps all students increase their communication, organizational and professional skills. The IEEE student branch is one of the main resources to meet and interact with professionals working in industry.

Embedded system engineering education is evolving. The technology to be learned by the students and the skills they need to gain during undergraduate study is changing fast and enormously. As professors train the next generation of embedded system engineers, we need to update both our technical skills and teaching skills. We should quickly adapt to student-centered education. This is really changing in most cases. In most cases, student interest level, motivation and background are not uniform. Our purpose is not to filter out good students but keep all of them busy trying to do their best. We need to develop an environment which is beneficial to all the students. We should always be open to incorporate digital media, internet resources, and simulation programs as part of the learning process. Engineering students are interested in having hands on experience, being able to solve problems, designing and testing something related to class and part of everyday life.

Continuous pursuit of improvements in teaching and learning using scientific methods depends on interaction. Reviewing educational improvement efforts in all disciplines will be beneficial to our program too. Improved education in all STEM programs will be helpful for increasing student enrolment and retaining them in these programs. Last question is “how can we measure success of the methods used?”. Feedbacks from students, recent graduates, employers, and members of PAB are the best resources for this.

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Summer Camp Exposes Middle-School Girls to Engineering

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Abstract

Attracting female students to the field of engineering is a challenge. Students' interest must be captured before societal pressures deflect career choices into other directions. Students, particularly females, must be encouraged to consider engineering as an interesting field before it is "too late" to enter the necessary math and science tracks in high school. Consequently, female students must be exposed to the excitement and potential of engineering during their middle-school education to motivate them successfully to consider engineering careers.

At the University of Minnesota Duluth (UMD), a summer camp was developed to offer engineering exposure to girls entering middle school, grades seven and eight, in the Fall. During this camp, these girls explored technical topics and actually designed solutions to engineering problems. For this first offering of the camp, the curriculum was developed by Electrical Engineering faculty at UMD, and so focused on electrical phenomena and electrical applications, although the camp may broaden to include other engineering disciplines in future offerings.

In this first offering of the engineering camp, students experienced several different electrical technologies that have high visibility in middle-school-aged students' lives. Topics addressed in this camp included solar energy, light-emitting diode (LED) applications, and digital circuit design. The camp was structured around fun activities to hold students' interest, but demonstrated technical material behind the scenes so that students could look back on their experience with a healthy combination of pleasure and wonder. The goal of the camp is to dazzle the students with fun applications that engineering makes possible, without intimidating them with undue complexity or technical details.

This paper will describe the engineering camp curriculum as presented to middle-school-aged girls. It will detail the activities and experiments in which the girls participated. Finally, it will evaluate the camp experience and suggest ways to improve future camp offerings.

Camp Schedule

This engineering camp for girls was offered during one week, Monday through Friday, in the late summer of 2012. It was a day camp only. Campers were on campus from 9 AM until 4 PM each day, and were our responsibility during that time. Socialization was an important part of the camp's activity, with the goal of campers interacting easily and making new friends. Our job was to introduce basic engineering concepts, while making this experience fun and memorable.

On Monday morning, campers were engaged with a number of ice-breaker activities, and in the afternoon completed an easy project involving solar energy. On Tuesday, campers spent all day

learning digital circuit basics. They designed and assembled digital circuits to accomplish assigned tasks. On Wednesday morning, the girls were introduced to some electronic instrumentation, and that instrumentation was used in the afternoon in some analog circuit applications. Campers spent Thursday constructing a design project that incorporated some electronics and also provided opportunity for artistic and creative expression. Friday included time for completing Thursday's project, experimenting with more solar activities, and showing off for family members in an open house presentation which included awards for the campers.

Monday

To begin the engineering camp, the girls and instructors were introduced and then asked to participate in an ice-breaking activity (*Figure 1*). This gave them opportunities to explore the Electrical Engineering department's facilities informally, and to interact with each other. For example, campers were asked to find the office room numbers of the camp's faculty, and to find another camper with their same eye color. The girls were also given a tour of the UMD campus to help them feel comfortable in their new environment.

After lunch, campers assembled and decorated solar "bugs" as their first engineering project. These bugs consisted of a cell-phone vibrator motor wired and hot-glued to the bottom of a small solar cell with paper-clip legs (*Figure 2*). In the sunlight, these bugs bounced around on smooth surfaces and provided some insight into solar power.



Figure 2: Solar bug

A popular part of this project was decorating the bugs. Using hot glue, the girls added feathers, eyes, and other features to their bugs. This decorating process was a design activity in itself, but soldering the motor to the solar cell also provided some more technical experience to justify the engineering aspect of the project. The solar bugs were the first tangible product designed by the participants in the camp, and they were judged for awards at the end of the week.

Tuesday

Tuesday was devoted to basic-level digital circuits and digital design. Campers learned about digital system fundamentals and digital components, including AND, OR, and NOT gates and D flip-flops. Standard breadboards were issued to the girls, and their use in building circuits was described. Components and their pinouts were supplied and described.

Experiments #1 and #2 (*Figure 3*) were performed in the morning as a group, with step-by-step guidance from the instructor. Campers had six D flip-flops (one 74LS174) and seven two-input NAND gates (two 74LS132s) with which to design their circuits. (One NAND gate was used to generate a 2 Hz clock signal for use by the flip-flops.) Campers implemented functions to light various segments on a common-anode seven-segment LED display using the supplied breadboard. The components were pre-inserted on the breadboards with power and clock connected, so that the campers had to add only the wires implementing their logic. Power was supplied by a 6-volt lantern battery for each camper, including a series rectifier diode to reduce the voltage to a safe 5.3 volts for the TTL components, and to protect against reverse polarity.

Find a girl whose shoe size is the same as yours or someone whose size is 3 or more sizes apart from yours. Her name is _____.

Pick up a paperclip from Scott Norr.

Do a fake 3-legged race with a girl you hadn't met before today in front of Jerald.
Jerald's initials _____.

Find a girl with the same eye color as yours. Her name is _____.

Whisper the Happy Birthday song to a girl you hadn't met before today.
Her name is _____.

Shake hands with a girl you hadn't met before today and continue holding hands while telling her your favorite family vacation story, and then listening to hers.
Her name is _____.

What office number is Prof. Bai's? _____.

Play ring-around-the-rosy with at least 2 other people.
Their names are _____.

Collect one dried leaf.

Find someone you hadn't met before today who has a different birthday month than you.
His/her name is _____.

Get a rubber band from Dana.

Prof. Carroll's office number is _____.

Race from the outside door to the glass dome with someone. Her name is _____.

Find someone you hadn't met before today with the same type of pet as you.
His/her name is _____.

Bring in one blade of grass.

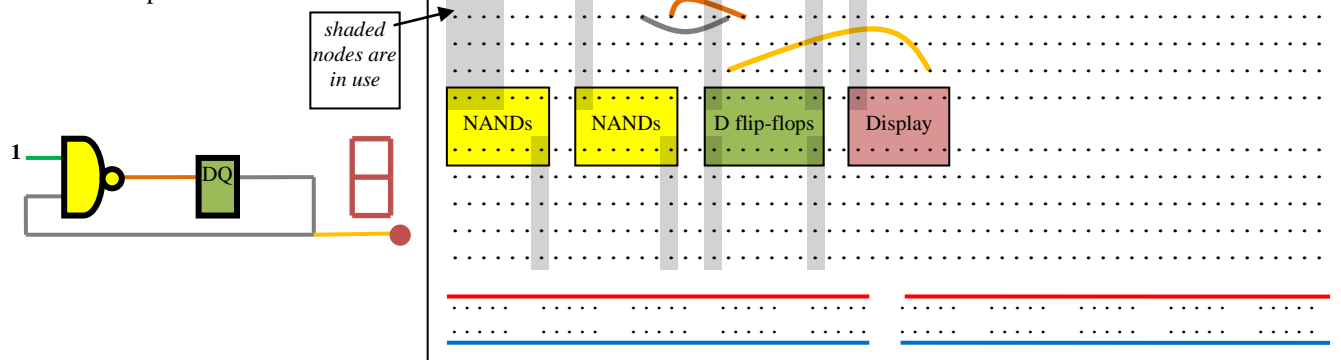
Stand on one foot with your arms outstretched for 30 seconds in front of Steve. Have someone time you. Steve's initials _____.

Find out the middle name of someone you hadn't met before today.
His/her full name _____.

Figure 1: Ice-breaker activity

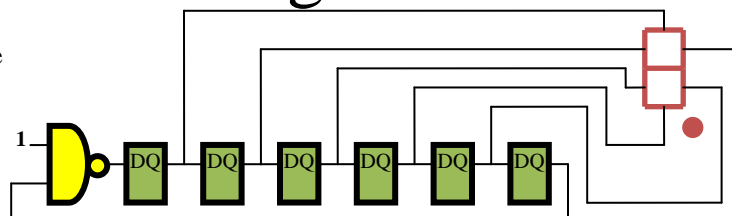
Experiment #1: flashing light

Build the circuit shown below. Each time the clock ticks, the flip-flop changes state and the decimal point blinks.



Experiment #2: twisted-ring counter

Build the circuit shown at right. The contents of the six flip-flops shift to the right one position per clock, and the right-most flip-flop output is reversed and fed back in on the left. The pattern repeats every twelve clocks.



Experiment #4: show your initials

Using a four-state twisted-ring counter (see Experiment #3), design and build a circuit that displays your initials, one at a time, on three consecutive clocks, shows a blank display on the fourth clock, and repeats that sequence forever.

Suggested 7-segment letters

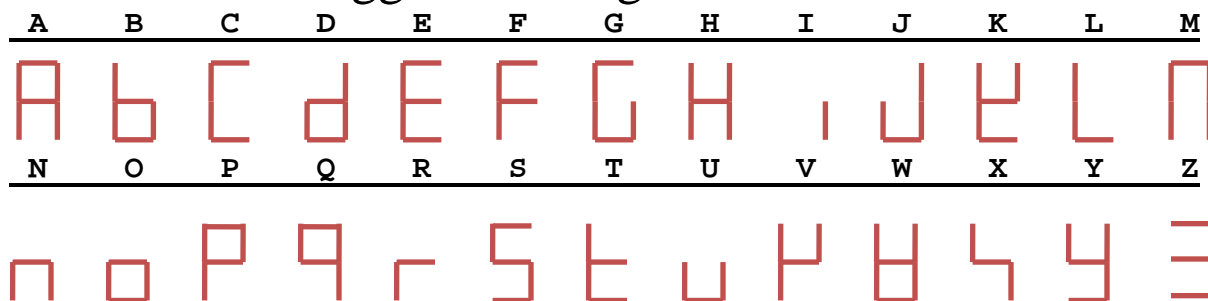
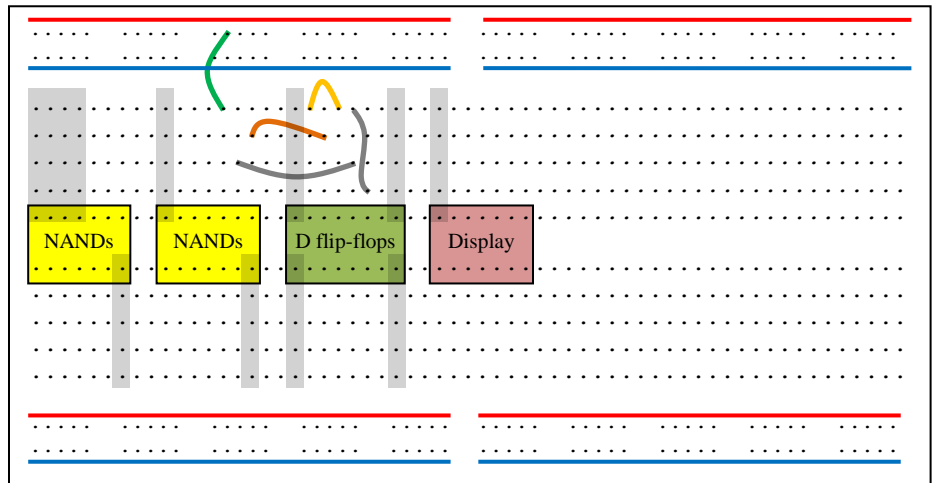
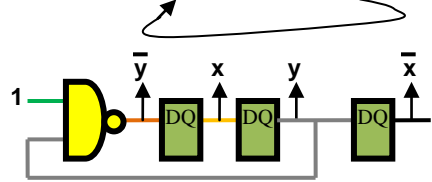





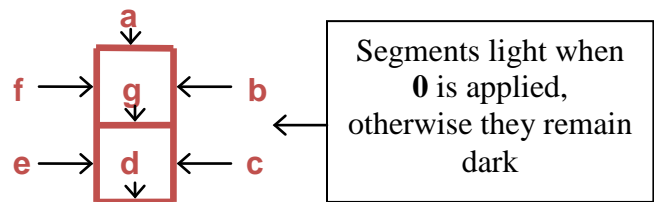
Figure 3: Digital circuit experiments #1, #2, and #4

Experiment #3: show Fun

Build the circuit shown below.
Each time the clock ticks, the
flip-flops advance through the
sequence **xy = 00→10→11→01**.

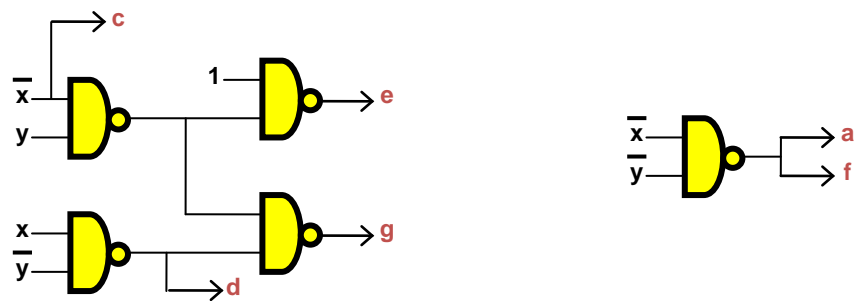


x	y		a	b	c	d	e	f	g
0	0		0	1	1	1	0	0	0
1	0		1	1	0	0	0	1	1
1	1		1	1	0	1	0	1	0
0	1	(blank)	1	1	1	1	1	1	1



Add additional wires to implement the functions shown above for the segments. There are many solutions!

Solution #1:



Solution #2:

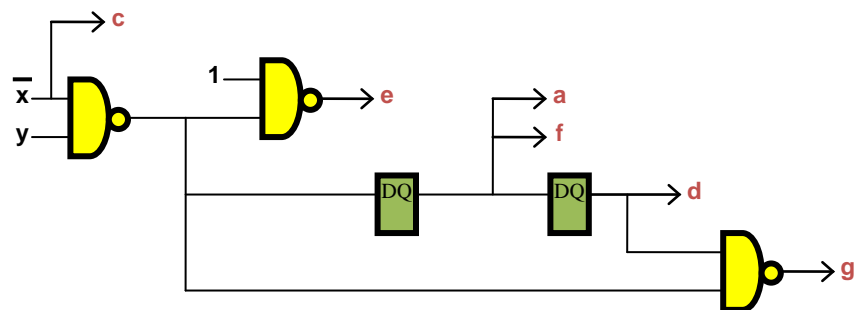


Figure 4: Digital circuit experiment #3

During the afternoon, Experiment #3 used the seven-segment display to show a message, “Fun_,” one character each half-second (*Figure 4*). The basic four-state counter (top of *Figure 4*) was constructed and de-bugged as a group but then, after hearing a description of the functions for the seven display segments, campers were encouraged to design circuits to implement the segment functions on their own. This was mostly unsuccessful, but a few of the girls were able to accomplish the task (*Figure 5*). The solutions shown on *Figure 4* were discussed as examples of possible approaches.

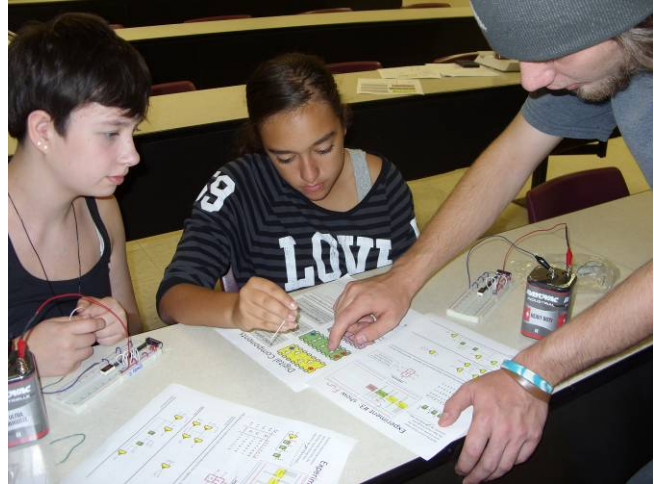


Figure 5: Digital circuit Experiment #3

Finally, Experiment #4 (*Figure 3*) encouraged the campers to design their own message, following the template of Experiment #3 but replacing the message with their three initials or a three-letter word of their choice. This experiment proved to be too ambitious for the girls to solve completely, but it did provide an example of engineering design that required innovation and creativity. Campers were allowed to keep their breadboards, digital components, batteries, and wires in the hope that they would explore digital circuits further on their own after camp.

Wednesday

On Wednesday morning, campers were shown electrical equipment, including function generators and oscilloscopes, which they would use later that day in some experiments. As an introduction, a function generator was used to produce a sine wave, initially at just 1 Hz, so that the girls could observe the dot on the oscilloscope moving up and down. Gradually, the frequency was increased, and the oscilloscope horizontal time base adjusted to display waveforms for not only the sine function, but also triangle, ramp, and square wave outputs of the function generator (*Figure 6*). Then a second function generator was added to control the horizontal axis of the oscilloscope display and Lissajous figures were explored with various frequency ratios on the horizontal and vertical signals. This experiment was a hit with the campers.

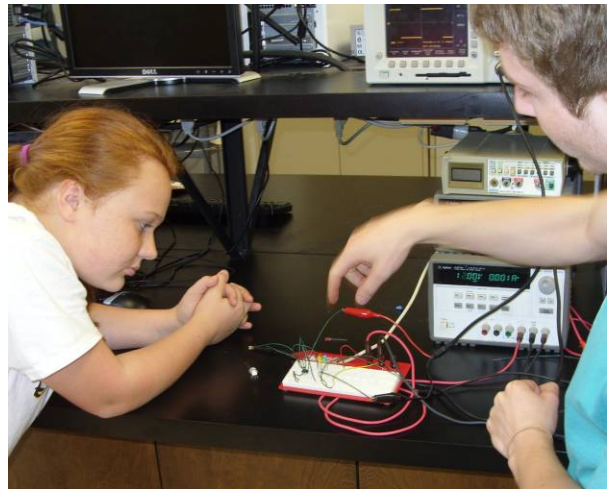


Figure 6: Experiments with instrumentation

Later that morning, campers observed a demonstration of how accelerometers control airbag deployment in automobiles. A simple LED indicator was used to simulate the airbag, and an accelerometer was mounted in a toy car, which was driven into walls to simulate crashes,

lighting the LED indicator. This experiment was fun and related to real life experiences with airbags in cars, but did not allow the campers to actually perform hands-on work themselves.

Later in the day, campers explored op-amps and circuits built with them, without attempting any calculations or circuit design activities. They built open-loop amplifiers to produce square wave outputs from sine wave inputs, and explored using op-amps as comparators for analog voltages. To conclude this activity, campers built a pre-designed circuit that lit one of three LEDs based on the voltage supplied on an analog input.

To finish Wednesday activities, campers used hot glue, LEDs, and button-batteries to create lighted brooches, pendants, or other jewelry (*Figure 7*). This gave the girls a chance to express themselves creatively in a hands-on activity, and produced another tangible result of the camp that was later judged to determine an award on the camp's final day.



Figure 7: LED jewelry

Thursday

Thursday was spent modifying and decorating toy cars. The body of the car was removed, so that the campers had just the bare chassis as a foundation (*Figure 8*). Campers re-wired the battery and motor in the car to incorporate a light sensor photocell and transistor that controlled the on/off status of the motor. The photocell was mounted on the back of the car so that it could be illuminated by a handheld laser aimed at the photocell to make the car run. The result of this exercise was to produce a car chassis that could be raced in a competition, with the campers controlling their cars by shining lasers on their cars' photocells from behind. This modification was the goal for the morning's activity.



Figure 8: Car chassis



Figure 9: Decorated car body

The afternoon was spent with each girl designing a creative body for her car chassis using a cardboard milk carton, hot glue, decorations, and paint (*Figure 9*). This afternoon was great fun for the girls as they were able to express themselves creatively. The morning's activity of adding the photocell control electronics to the car provided the engineering content for this project. The afternoon was just for fun, and was a great way to conclude the technical content of the engineering camp. The girls' completed cars were judged to determine another award presented on the final day of the camp.

Friday

Friday wrapped up activities for the camp. In the morning, campers spent time completing their customized car bodies to prepare the modified cars for a race competition in the afternoon. One more engineering activity took place on Friday, construction of solar “ovens” using pizza boxes from lunch and aluminum foil, with the goal of “cooking” s’mores as a treat to end the camp. The goal was not completely met (note the melted chocolate but uncooked marshmallows in *Figure 10*) but the campers had fun and still enjoyed their treats.

In the afternoon, family members visited their campers for an open house, during which awards were given for the best solar bug, best LED jewelry, and best laser car, as selected by the camp participants. Also, each camper received an award determined by the camp faculty and staff. Examples of awards included **Most Determined**, **Best Solderer**, and **Best Engineer** (*Figure 11*). Although the laser cars were never raced, they were demonstrated to family members, providing the campers with a great opportunity to display their creativity and newly attained engineering skills.



Figure 10: Solar oven with s'mores



Figure 11: Best engineer!

Assessment

Campers were asked at the end of each day to complete a form identifying their favorite and least favorite parts of the day, and asking for suggestions for improvement. These girls universally had a great time in the camp. They had no constructive suggestions for improvement. Their least favorite parts of the week involved sitting still for “long lectures” and the most favorite parts of the week involved creative activities such as decorating the solar bugs or laser cars with hot glue, feathers, etc. These responses were not surprises, but will lead to restructuring the camp in the future to break up classroom activities into shorter segments.

On Friday during the open house, both the girls and their family members completed more detailed questionnaires about the camp experience. These forms asked again for favorite and least favorite camp experiences throughout the week, but also sought feedback on how the camp was run and how comfortable the campers felt interacting with fellow campers and with the camp faculty. Again, the girls reported that the whole experience was fun, and several suggested that they would like to participate again next year. Family members reported that the girls talked about their camp experience at home enthusiastically and looked

forward to returning for each day's activities. Some responded that the girls' vocabularies had become more technical and that they were discussing topics from camp that they had not considered before.

One politically charged question asked responders to comment on having this be an "all-girl" camp. Almost universally both the girls and their families agreed that limiting the audience to just girls allowed the participants to be more comfortable and natural, and allowed the girls to focus on the engineering topics without being distracted or inhibited by the presence of boys. Many of the camp activities, such as LED jewelry design, targeted the female audience, and might not have interested boys. Most of the girls themselves responded that they enjoyed the camp experience more without the presence of boys, and the family members emphasized that the presence of boys at the camp could have cramped their girls' creative expression in some of the activities. Overall, the design of the camp seemed to meet the needs of the audience very effectively.

This first offering of the engineering camp for girls was a success. Because it was our first attempt at offering such a camp, the experience was offered for free to participants. However, one of the questions asked of family members was if their camper would have participated even if there were a camp fee, and what should the fee be? Most respondents indicated that the camp experience would be well worth a small fee, at least \$50 per participant, with some responders suggesting even higher fees.

Summary

This engineering camp for girls was a successful first attempt at conveying engineering ideas to middle-school girls. Several ideas for improvement, such as breaking up long lectures, minimizing "classroom" time, and maximizing hands-on activities will be incorporated into potential future offerings of the camp. Although it will be at least six years before the participants of this camp may enroll in a college engineering program, this long-term planning is the best way to address the goal of increasing the proportion of women in engineering.

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Reflection and Note Taking used in Active Learning

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Abstract

Reflective practice and reading are important elements of active learning for college students. Reflective practice exercises using the one minute paper and case studies can help students develop critical thinking skills. Individual reflection along with small group reflection enhances student learning by understanding advantages and disadvantages of subject material. Reading incorporated with note taking can help students improve their skills in gathering and retaining important course information. Note taking can be a valuable tool in helping students read more efficiently and effectively.

Reflective Practice

What is reflective practice? How can students engage in reflective practice and what are the benefits? Engaging students in reflective practice exercises includes the one minute paper, and case studies. Both of these reflective exercises can help develop critical thinking skills. Reading along with note taking can help college students gather and retain information more effectively. The reflective exercises will be discussed along with reading and note taking examples. Also, further explanation of reflective practice will be discussed.

What is the definition of reflective practice?

There is no universally accepted definition of reflective practice but a multitude of perspectives. In reading definitions of reflective practice, consider your own way of defining reflective practice so that this can become an organizer for your own thinking and learning. (York-Barr, Sommers, Ghere, & Montie, 2006, p. 8) ¹

This process of a person organizing how to think and learn can be done as an individual, with a partner, or various sizes of groups.

When does a student engage in reflective practice? Reflective practice can be considered to be a process that individuals can be engaged in during critical thinking, evaluating positive and negative attributes, and understanding the meaning of a topic or a problem. “What kind of thinking is prompted when you engage around a problem, event, or puzzle of practice” (York-Barr et al., 2006, p. 8)? ¹ The engagement of a problem is universal for individuals and groups to solve. Another definition of reflective practice that can be considered for students centers on the word improvement. “Reflective practice is a meaningful and effective professional development strategy. Even more, it is a way of thinking that fosters personal learning, behavioral change and improved performance” (Osterman & Kottkamp, 2004, p. 1) ².

Engaging in problem solving is a common discipline or skill set needed when working for industry as a professional or working as a student in academics. “Most of us, however, are rarely introduced to the concept as part of our personal or professional development “(Kelleher, 2011, p. 1) ³. The actual concept is not discussed in most industry and business settings but if it was

introduced according to Kelleher (2011)³, it could have positive results. “However, where there are business drivers to support new ways of working, it may be possible to introduce reflective practices that have long-term benefits to the organization” (Kelleher, 2011, p. 1)³. Teaching college students how to engage in reflective practice can help them to transition into the workforce more effectively and provide overall positive results.

Another definition of reflective practice that can be used for professionals in either industry or in teaching centers on the word improvement. “Reflective practice is a meaningful and effective professional development strategy. Even more, it is a way of thinking that fosters personal learning, behavioral change and improved performance” (Osterman & Kottkamp, 2004, p. 1)². Improving performance is essential to achieve as a professional in both industry and in academics.

The One Minute Paper

A reflective teaching exercise used in the classroom of this instructor and author of this paper, is called the one-minute paper. “A one-minute paper may be defined as a very short, in-class writing activity in response to an instructor posed question, which prompts students to reflect on the day’s lesson and provides the instructor with useful feedback” (“The One-minute Paper,” 2012)⁴. During the one-minute paper assignment, students are to reflect on a presentation or classroom activity and come up with questions to ask the person presenting the information. Student responses are saved and used for activities later in the semester. Samples of the questions used in this activity to promote reflection are as follows: List three interesting ideas or concepts you observed today during the presentations and explain why they were of interest to you. List two follow-up questions that you have based on the presentations today. These questions are used along with others to promote thoughtful deep thinking.

Case Studies

Active learning and reflection exercises include the use of case studies in the classroom. When thinking about a problem to solve a reflective person generally will not jump to conclusions immediately. One, who is considered to be reflective, will try to gather facts first and then act on the information collected. Case studies help college students find practical ways to solve problems that relate to the industry they are studying and are real world examples. Real world examples help students to connect, remember and understand information for sensing learners (NC State University, n.d)⁵. College students need to learn how to apply common sense and to find practical and multiple ways in solving problems because there are generally multiples variables affecting real world problems.

Reading and Note Taking

Another form of active learning is reading and note taking. A teaching strategy used in the classroom of this instructor is to allow students to use notes on exams and quizzes. Note taking is a tool to help students gather and retain information. When a student is attempting to answer an exam or quiz question, a note sheet helps the student to search for facts relative to the question. The quality of notes can directly reflect the students’ ability to make a decision. Note taking is also a reflection of reading and then writing down facts pertaining to the information. The

writing down of information read can reinforce the learning of the material. A student, who makes a detailed note card prior to an exam, has taken the time to logically research facts and information, and this often reflects positively on their overall outcome of their exam.

A note taking example used for an exam in a college freshman class this educator instructs provided measureable results. For the first exam, this author encouraged all the students to use notes because of the amount of material covered (average of four chapters) and that notes are a good way to gather and retain information. According to (Longman & Atkinson, 1999)⁶, notes help aid a student in both comprehension and retention. These authors also revealed that if important information was contained in notes a person has a 34 percent chance to be remembered, if not only a 5 percent chance to be remembered. I revealed to the students how the average in the first exam scores directly related to good note taking practices. Students are allowed to use both sides of one 8.5" x 11" sheet of paper and can have either typed or hand written notes. The author of this paper collects the student's notes for review. This class consists of 47 students and fifteen of the students did not have any notes for this exam. The average score was only 57 percent for students with no notes. Students with only a small amount of notes had an average score of 65 percent. Students with one side of the page filled with notes averaged 75 percent. The best results being, the students with both sides of the page filled with notes averaged 85 percent on their first exam.

The purpose in sharing this information to the students was to encourage the students to use note in the future exams and how it directly related to their test scores. This author shared ideas with the class about how to take good class discussion notes and how to collect data while reading their assignments. This note taking tool helped students to perform better on their next exams. The students had higher quality and quantity of notes that directly reflected better test scores.

Summary

In summary, reflective practice is a form of active learning and can be accomplished through exercises such as the one minute paper and case studies. Benefits of college students engaged in reflective practice exercises can help to develop critical thinking skills. Another form of active learning is reading along with note taking. This can help college students gather and retain information more effectively and help to improve exam scores. The active learning exercises discussed in this paper can help college students understand and to apply the information they are being taught.

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Using a High Altitude Balloon Satellite Prototype Project for Systems Engineering Skills Development

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High altitude balloon (HAB) missions have previously been used to teach and test concepts related to space and satellite design [1, 2]. However, the learning experience is impaired by the need for most students to learn a space-specific design and engineering framework. Additionally, HAB missions have their own unique characteristics, which must be taken into account in order to be successful. Designing a satellite to fly as a HAB payload, unaltered, would be as inappropriate as flying a HAB payload as a satellite.

This paper discusses an approach to solving this problem using a formal process for designing HAB missions, based on widely accepted space mission engineering techniques [3, 4]. The accelerated, three-phase, process begins with the consideration of objectives, needs, requirements and constraints. Phase two involves the development of the mission concept and architecture. Phase three includes the identification of drivers, definition of requirements and analysis and selection. The approach is simple enough to be rapidly learned and not weigh-down a project. It also provides initial understanding that simplifies learning the extended frameworks.

The alignment with industry-standard mission analysis and design techniques makes the proposed process suitable for use as a one-semester introduction to space mission engineering. Further, it facilitates an escalation to heavyweight processes for higher cost, higher risk and/or longer-term projects while still providing valuable insight on considerations unique to balloon missions.

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The Use and Evaluation of “Partner Quizzes” in a Computational Methods Course

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Abstract

This paper examines the use of partner-based quizzes as a tool to encourage active learning in a Computational Methods course. The course under consideration is a sophomore/junior level course which combines an introduction to computer programming with an introduction to numerical methods. Partner-based quizzes have been incorporated into the course structure to promote active learning in a team-based environment. Ten quizzes are administered during a 15 week semester with students being assigned a different partner for each quiz. Approximately fifty percent of a student's grade is derived from the student's performance on these quizzes.

A focal point for this paper is the systematic approach that has been devised to assign partners for each quiz. Partners are assigned based on performance on previous quizzes. A pattern of combinations involving “like-score” (matching students with similar scores), and “opposite-score” (matching high scoring students with low scoring students) is used to promote an appropriate blend of partner interaction and individual responsibility. The combinations are also formulated so that the cumulative quiz grades are an effective indicator of overall individual performance. The results indicate that students tend to prefer the partner quiz format. The partnership approach provides a forum to teach students how to form increasingly better partnerships as the semester progresses. Cumulative quiz grades also align well with student performance on other grade items indicating the ability to effectively assess individual performance in a partner-based environment.

Introduction

The classroom environment has a traditional focus on individual effort and achievement. As such, the incorporation of group tasks into the classroom poses many challenges to both the students and the instructor. These challenges include the preparation for a group exercise, the motivating of the exercise, distributing students into appropriate groups, ensuring participation of all students, and evaluating the exercise which includes the performance of groups and the individuals within the groups. This list of hurdles is enough to dissuade even the most intrepid instructors, but the task need not be so daunting. One approach to simplify the task is to leverage the tools of individualized classroom instruction to develop a group environment. One tool that is particularly amenable to this is the common quiz. This paper will examine the use of quizzes to develop a group-based active learning environment in the classroom.

The focus of this paper is the use of “partner quizzes” to develop an active learning environment in an introductory course in Computational Methods. The rationale for the use of partner quizzes is derived from several sources. The first is the ease of integration into the classroom environment. Students are accustomed to quizzes and exams, so the idea of working with a

partner on a quiz is simply an extension of a familiar exercise. A second motivating point for the use of partner quizzes is the opportunity to introduce a group dynamic into the classroom. Recent research¹ indicates that cooperative learning results in higher academic performance when compared to individualistic learning. A third reason for using partner quizzes is the natural motivation associated with quiz taking. Calling the exercise a “quiz” provides a heightened sense of urgency and motivation that might not exist under another name (such as “homework”). Partner quizzes provide a relatively simple means to introduce active learning into the classroom using a format that is already familiar to students.

One of the challenges associated with any group exercise is the effective evaluation of the results. Instructors have long struggled with the development of methods to separate individual grades from a group effort. A variety of authors have presented approaches to this problem. These include Johnston and Miles², Kaufman et al³, Lejk and Wyvill⁴, and Zhang⁵, among others. Popular among the grading approaches are various uses of peer evaluation, separation of individual and group assignments within the group, and instructor intervention methods. Partner quizzes, as used in this paper, appear to be somewhat unique in their ability to maintain the group environment without the need to introduce additional measures to separate individual grades. Grade separation occurs naturally through a systematic rotation of partners.

The remaining sections of this paper describe the use of partner quizzes in detail. The first section describes the course environment and the implementation of partner quizzes to create an active learning atmosphere. The second section discusses the rotation of partners and the influence of this rotation on grading and active learning. A final section examines the results and student response to the methods while also posing ideas for further development.

The Course and Quiz Environment

While the ideas presented in this paper could be implemented in a variety of courses, the specific focus of this paper is on the use of partner-based quizzes as a tool to encourage active learning in a Computational Methods course. The course under consideration is a sophomore/junior level course which combines an introduction to computer programming with an introduction to numerical methods. The three credit course meets for two hours, twice a week. A first hour of each meeting is devoted to lecture time with the second hour of each meeting dedicated to problem solving exercises in the computer lab. Partner-based quizzes are a primary component of the problem solving exercises with the objective of the quizzes being to promote active learning in a team-based environment.

In the most recent offering of the Computational Methods course, ten quizzes were administered during a 15 week semester. Students were assigned a different partner for each quiz. During the time leading up to each quiz (a duration of 1-2 weeks), partnerships were responsible for working together to develop solutions for a set of homework problems that would provide the basis for the next quiz. The culmination of each partnership would be the completion of a quiz where the problem to be solved was some variation of one or more homework problems.

Active learning was encouraged in the above format using several methods. The first of these is the use of the pre-quiz work periods to assign partners for the upcoming quiz. Once partners are assigned, they are expected to collaborate on homework during the computer lab time in

preparation for the upcoming quiz. Unfortunately, partners did not always take advantage of this time to work together, so a second method was introduced to more strongly encourage partners to work together. The second method was the requirement that each person in the class review the current status of his/her partner's work. Each partner would then submit a check sheet at the end of the lab time indicating progress on the homework problems. Options for the check sheet included: a) no progress; b) problems started but not complete, and c) problems complete. This requirement seemed to improve partner interactions during the non-quiz lab periods.

The final active learning exercise was the quiz itself. Student pairs were given an hour to complete a computer programming task related to one or more of their homework problems. Each team was required to share a single computer and submit a single solution. Further interaction was encouraged by requiring the students to "change drivers" (person in charge of the keyboard) every five minutes during the quiz. With this requirement, even if one partner knew how to solve the quiz and the other did not, they would still have to actively engage with one another as they alternated turns on the keyboard.

While the "outcomes" section will discuss the student response to the above in more detail, several instructor observations should be mentioned here. As noted above, students tended to want to work independently in the pre-quiz work periods. The introduction of the partner check sheets greatly increased the partner interaction during the preparation hours. The quiz period also proved to be a great time of interactive learning. During this time the computer lab was "buzzing" with the sound of conversation as partners worked together and exchanged ideas. Very seldom was a group found sitting silently with one person simply watching his partner at work. Occasionally a group would reach an impasse in their problem solving and be found sitting silent, staring at the computer screen. In these cases the instructor might intervene with a "hint" to enable such a group to continue to move forward in their discussion and solution.

The format described above resulted in a visible increase in student engagement and interaction during classroom hours. The methods have some promise for continuing use. Such continuing use, or implementation in other classes, hinges not only upon the promotion of active learning, but also upon the ability to address some practical issues of group learning. The next section examines the challenge of evaluating individual performance in the partner-based environment.

Partner Rotation and Separation of Grades

As noted in the introduction, one of the dilemmas of group work is the separation of grades for the individuals within the group. In the case of partner-based quizzes, this is resolved in two ways. First, the two person group size simplifies the problem by limiting the opportunity for an individual to "hide" among fellow group members. Secondly, the administration of multiple quizzes during the semester allows for the development of a rotation of partners to further separate individual grades. This section focuses on some strategies for rotating partners.

The course was formatted so that ten quizzes were offered during a 15 week semester. This gave students a specific objective for their partnerships every one to two weeks. Partners were changed for every quiz so that no student had the same partner for multiple quizzes. The partner rotation was set up to both sort and separate individual grades. The rotation included a combination of "like-score" matching (students of like scores matched, high scores matched with

high scores, low scores matched with low scores) and “opposite-score” matching (groups where a high scoring student is matched with a low scoring student).

The “like-score” matching was invoked to spread the grading scale. In theory, a pair of high scoring students will score high on a partner quiz while a pairing of low scoring students is likely to produce a lower score. As such, the “like-score” matching provides a means to spread the grades, separating the best students from the worst students.

One problem with “like-score” matching is the initial sorting of grades. The first quiz administered is done so using self-selected partners (students choose a partner). In this case, a high scoring student might end up matched with a low scoring student. The outcome of such a pairing is likely to be a high score. If “like-scoring” was used in all subsequent quizzes, the student who might normally be “low scoring” would simply bounce around with high scoring partners and continue to receive high scores that may not align with his capabilities. To avoid this scenario, “opposite-score” matching is invoked to sort grades. On the second quiz administered, each high scoring student is matched with a low scoring student. If a student was a “false high” on the first quiz, the partnership with a low scoring student will likely result in a low grade and tend to sort the students by their true capabilities.

Given the above matching schemes, a variety of combinations are available for their implementation. In the course under consideration, an alternating matching scheme was applied, as shown in Table 1. This scheme allowed for a continual sorting and separating of grades.

A final note on the partnership assignments is that students were unaware of the means for assigning partners. As far as the students know, the assignments were random.

At the end of the semester, students were surveyed to obtain their responses to the partner quiz format. The next section presents the results from this survey and examines the effectiveness of the sorting methods.

Quiz #	Matching Scheme	Purpose
1	Student Self-Select (SS)	Initial Sort
2	Opposite-score (OS)	Sort
3	Like-score (LS)	Separate
4	Opposite-score (OS)	Sort
5	Like-score (LS)	Separate
6	Opposite-score (OS)	Sort
7	Like-score (LS)	Separate
8	Opposite-score (OS)	Sort
9	Like-score (LS)	Separate
10	Opposite-Score (OS)	Sort

Table 1: Quiz Sorting Scheme

Outcomes and Student Responses

The two important issues for this paper are the extent to which students valued the active learning format of the partner quizzes and how these quizzes impacted student learning and their grades. This section examines both of these issues.

Feedback was obtained via a survey of students to obtain their responses to various aspects of the quizzes. The survey asked students to evaluate the quality of their partnerships throughout the semester and to identify the quizzes where they had the best and worst partner experiences. The survey also asked students about their preference for partner quizzes vs. individual quizzes and about the frequency of partner rotation. Space was also provided for comments.

When examining partner interaction, students were asked to identify the single quiz where they had the best partner interaction. The results are shown in Figure 1. Three quizzes stood out among students as those where they had the best interaction. These were quizzes 1 (20%), 7 (16%), and 9 (18%). Notably, quiz 1 was a student self-select where one would expect good interaction with students choosing their own partners. Quizzes 7 and 9 were late semester quizzes with a “like-score” selection, possibly indicating that students were forming better partnerships later in the semester and that they partnered better with students of similar ability. In general, the “like-score” partnerships (quizzes 3, 5, 7, and 9) produced more favorable partnerships.

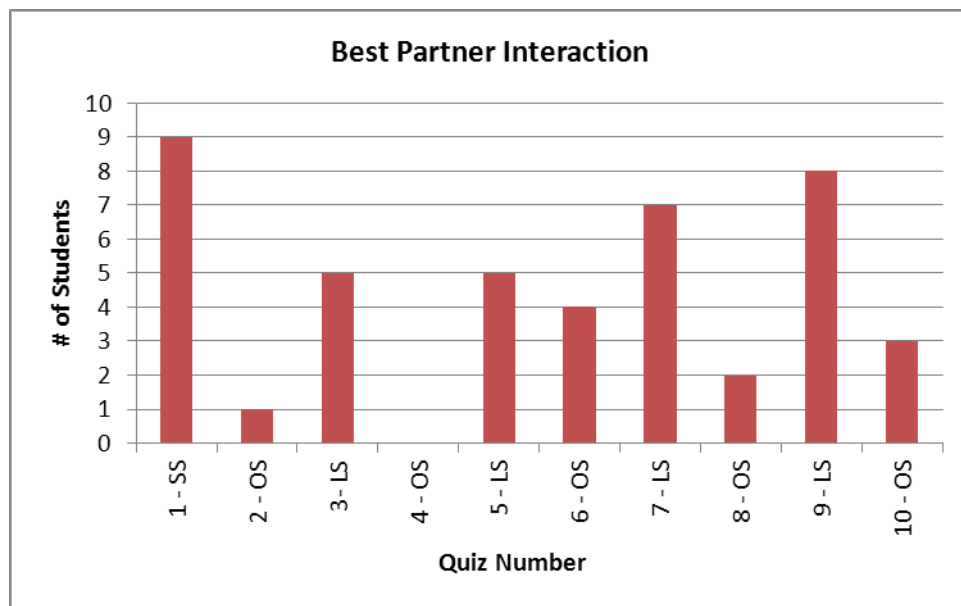


Figure 1: Graph of Best Partner Interactions.

On the opposite end, students were also asked to identify their worst partner interaction. The results are displayed in Figure 2. Two quizzes stood out in this regard, quiz 3 (20%) and quiz 10 (18%). The expectation would be that the early quizzes with “opposite-score” partners would have the worst interaction. Quiz 3 was an early quiz, while quiz 10 was an opposite-score partnership, but neither fits both categories.

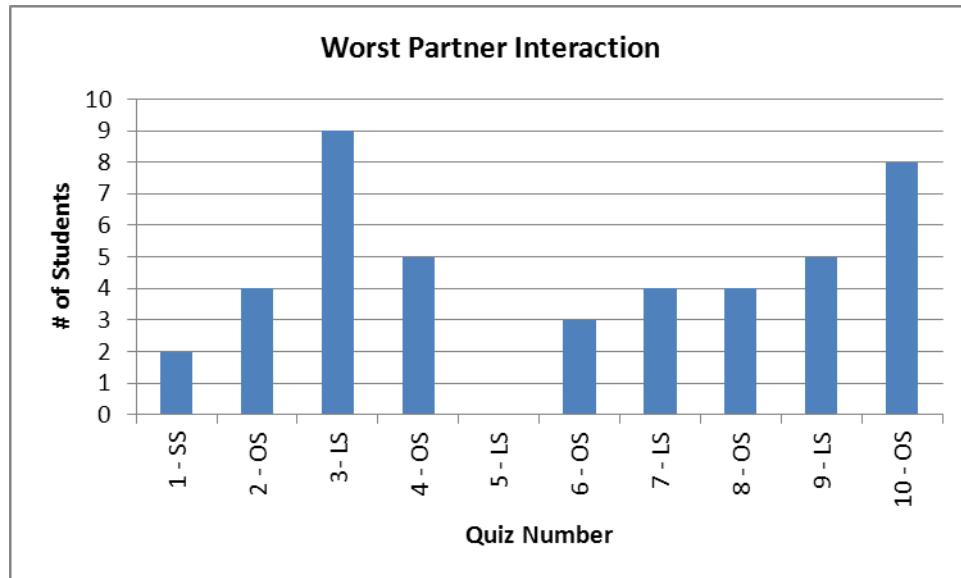


Figure 2: Graph of Worst Partner Interactions

In regard to the above results, an interesting note is that student comments tended to favor the “like-score” partnership scenarios. Some students expressed frustration that some of their partners were not well prepared, while other students expressed frustration at being “left behind” by their partners. Both of these cases are more likely to occur in opposite-score partnerships.

Students were also asked about their preference for partner quizzes. 70% of the students indicated a preference for partner quizzes, 10% for individual quizzes, and 20% for a mix of the two. One concern in regard to partner quizzes was the duration of the partnerships. A number of students appreciated the opportunity to meet and work with new people every week or two and were able to use those relationships to work together on other course assignments. Other students expressed concern that the partnerships were too short in duration for them to develop a good working relationship. Several students commented that the partner evaluation sheets that were implemented near the end of the semester helped improve their partner relationships.

Finally, in regard to the ability of the partnerships to sort grades, the sequencing of partners produced grades that roughly align with student grades on non-quiz assignments. Of the students that scored at or above the median total quiz grade, 75% of these students also scored at or above the median grade on the non-quiz assignments.

Conclusions and Recommendations

The overall idea of partner-based quizzes seems to work well, both for promoting active learning and for being able to separate student grades. This section briefly summarizes the things that seem to work well and presents some ideas for refining and improving the approach.

The biggest assets of partner-based quizzes are their ability to promote active learning in a group environment while also allowing for individual grades to be separated. With this in mind, some recommendations for ideas to continue in regard to partner-based quizzes include:

- Maintain a rotation of partners to allow for the identification of individual grades.
- Have students submit an evaluation of their own and their partner's progress and preparation prior to administering a quiz.
- Encourage interaction by having partners rotate responsibilities during the quiz.

The partner-based quiz concept as outlined in this paper might also be improved by several slight modifications. Some recommendations in this regard include:

- Allow partnerships to mature. This would mean fewer partnerships with each partnership lasting 2-4 weeks instead of 1-2 weeks.
- Institute a higher percentage of "like-score" partnerships. This needs more study, but initial results seem to indicate that students prefer to work with other students of similar capability. This is also likely to enhance student learning.

The above recommendations for the partner-based quiz approach should allow for an active learning environment that can be implemented in a variety of courses.

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