Using Webpages to Document and Assess Student Capstone Project Work

Byron Garry
South Dakota State University

Abstract

A Capstone course is a requirement for all Engineering Technology programs, under ABET-TAC standards. In the South Dakota State University Electronics Engineering Technology Capstone course, many of the ABET-TAC Program Outcomes are assessed using the direct evidence of student's work. The Capstone course has, for several years, required the use of group project webpages, which the students create and maintain during the course of the project, in order to help the student groups collaborate and to document their project. As the university changed its course management system, software to implement the webpages was not available for one year. Ironically, this provided an opportunity to measure, using rubrics, the positive impact the use of project webpages have on the quality of final project reports and in assessment of some of the program outcomes, which are detailed in this paper.

Capstone Course and Outcome Assessment

The 2010-11 ABET-TAC Criterion 4. Curriculum section states that "Capstone or other integrating experiences must draw together diverse elements of the curriculum and develop student competence in focusing both technical and non-technical skills in solving problems"[1]. A short search of ASEE Conference papers variously defines the goal of the Capstone experience is "to integrate the engineering and management disciplines into a single comprehensive educational experience"[2] ,"to provide a bridge for the students to cross between the academic world on one side and the technical professional world on the other"[3] , to "provide an extensive platform to practice engineering design and to facilitate the integration of what students have learned throughout their curriculum"[4] ,"to better prepare graduates for engineering practice"[5], and "to demonstrate their abilities to potential employers."[6] All of these statements are valid. Using the measured outcomes of a Capstone course to assess how well students are prepared for engineering practice makes up an important and growing task for engineering and engineering technology programs.

McKenzie[7] reported in 2004 the results of their survey of all ABET-accredited engineering programs, where they asked about the characteristics of capstone projects, including its duration, importance in the undergraduate curriculum, and practices using the capstone design projects to fulfill EC 2000 Criterion 3 and Criterion 4 requirements. They reported that 80% of the respondents said that each of Criterion 3 outcomes can be assessed within the capstone experience, with the most commonly assessed Program Outcomes being: Communicate effectively, Solve engineering problems and Use engineering tools. They further reported 91% required a final written report. Respondents also reported evaluating many other items for assessment including student surveys during and at the end of the course, self-reflection entries in journals, self-reflection papers, alumni surveys, notebooks, log books, student written user's manuals, exit surveys, and assessments by a consortium of faculty.

Gloria Rogers, ABET's Managing Director of Professional Services, writes extensively on the topic of assessment. In an article entitled "When is Enough Enough?"[8], she says that data collection activities must be examined in light of good program assessment practice, efficiency, and reasonableness. She says several questions need to be asked, such as, "Is there a clear vision of why specific data are being collected?" She answers, "Without clearly defined outcomes, there can never be enough data because there is no focus." The National Academy of Engineering[9] in 2009 issued a report called "Developing Metrics for Assessing Engineering Instruction: What Gets Measured is What Gets Improved". In that report they reinforced the idea that a sustainable evaluation system must not require implementation that is burdensome to faculty or administrators.

In the SDSU EET program, we are constantly re-evaluating the program outcomes and how they are measured by the assessment process. We believe that we have a good balance of data collection practices. The SDSU EET program has defined, with the approval of alumni and its industrial advisory board, sixteen Program Outcomes labeled (a) - (p). These begin with the ABET Criterion 3 Program Outcomes (a) - (k), and then add the Criterion 9, EET program specific requirements, and some SDSU required program outcomes, which are labeled (l) - (p). The EET program assesses student progress on the outcomes all through the curriculum, generally gathering data on no more than three or four outcomes per course, in order to concentrate on the outcomes important for that course, as Rogers [8] recommends. But in the Capstone course, twelve of the outcomes are assessed every year (see details later in paper). This is consistent with what McKenzie [7] saw in their review of Capstone courses. However, it does place a heavy burden of assessment data gathering on that specific course.

Capstone Project Webpages

One of the ways of reducing the assessment load in the SDSU EET Capstone course that we considered was to use student project group webpages to document the project design. We began requiring the use of project webpages in 2005, based in part on some of the research detailed below. For this paper, the author has looked at more examples of how some engineering schools, as reported mainly at ASEE Conferences, are using webpages in Capstone courses.

Stahl [10] in 1999 reported an early implementation of the use of webpages by the Architectural Engineering and Building Construction Department of the Milwaukee School of Engineering. The department set up project specific websites as a clearinghouse for project data, including text, graphical, and video data, with the data including everything from contracts and meeting minutes to final drawings and construction images. Faculty and students used these websites to communicate regarding course and assignment requirements, but more importantly as the mode for students to organize, archive, and display their work. At that long-ago (in web-years) time, they reported struggling with the set-up of the websites.

Course Management software, such as Blackboard, from Blackboard Inc., Washington, DC, was used by the Mechanical Engineering program at Ohio University [11]. Faculty members and the student design teams used Blackboard to establish and maintain a communications channel with each other and with external industrial experts and referees. They reported, without further detail, that many student design teams established their own web pages. In 2008 Brodie [12] reported that at the University of Queensland, a Learning Management system (not named) was used for on-line project-based courses. There, 70% of respondents either agreed or strongly agreed that the course structure, entirely done through webpages, had enhanced problem-solving skills and made effective use of prior knowledge.

The Electrical Engineering and Computer Science program at the University of Portland [3] required each student project team to maintain a project web site, which contained an up-to-date repository for all project information. It included pages for documents, meeting minutes, presentations, schedule, and other data such as critical design files. The instructor provided a "starter" web that used a standard theme and page hierarchy. Teams were encouraged not to customize the web, which can be a time sink, or use it for other purposes. It contained a home parent-page and child-pages for documents, meeting minutes, presentations, schedule, and other information. Each team could only publish their own web pages, while the instructor had full access rights to all student web folders, which provided evidence for outcome assessment.

At Carnegie Mellon[13] in 2009, proprietary software called DesignWebs was used to provide a method for students to organize, navigate and synthesize the documents and conversations that occur while designing an engineering artifact in a project-based course. This software provided a bird's eye-view that is otherwise not possible due to information scattered in design discussions and documents.

At Washington State University [14], the focus was on the development of group artifacts, the first of which was developing a collaborative website called WSU Wiki. Students actively develop the wiki with the intent that it will be used as a community resource, for self and group assessment, improvement of the course, and the benefit of future students. At Grand Valley State University [15] in 2009, Google on-line applications – Group, Chat, Sites, Mail, Docs, and Calendar – were used for their senior project management course. They reported many successes and few difficulties using these free software tools.

Rubrics

Rogers [16] says that a rubric is "an authentic assessment tool used to measure student's work". This paper is not about the value of using rubrics, but rather showing the use of rubrics in a specific Capstone course. Furtner [6] talked about the use of detailed rubrics for Senior Design proposals in the Purdue Electrical and Computer Engineering Technology program. The program faculty developed rubrics, that the students had access to, that were very specific about what needed to be in the proposals. They concluded that a detailed grading rubric can be used to help convey the engineering professors' grading expectations for technical reports and proposals. They also concluded that just handing the rubric out was not enough. They recommended going over writing samples and using the rubric to grade those samples, in order to help translate the "theory" of rubrics into applied knowledge, which can help students perceive that a detailed rubric can be used as a clear outline of grading criteria.

At Iowa State [4], the Industrial and Manufacturing Systems Engineering Department reported using rubrics in their Capstone course. They believed that the Capstone course should address as many of the department learning outcomes as possible. One of their main concerns was that all project groups show ongoing evidence of design progress, with the intent of simulating working for an engineering manager in industry as a newly-hired engineer. They used their webpage setup and rubrics to monitor the design process. They also reported that they had to develop and change their rubrics over time, as experience showed that new considerations arose over time.

Sealy [17] published examples of the rubrics they used for assessment of ABET Program Outcomes (a) and (b). His department spent a great deal of time talking about the workload necessary to properly implement the assessment process. They, as are most programs, were concerned that an assessment method which causes an undue burden on faculty would not be successful in the long run. They felt the use of standardized rubrics across the program helped lessen the faculty workload.

Assessment, Webpage and Rubric Usage in the SDSU EET Capstone Course

At SDSU, the EET 470/471 Project Management/Capstone sequence (two semesters) is a hybrid course, which in this context means the course uses two means of instruction: face-to-face class meetings for interaction and lectures and also uses D2L course management software, from Desire2Learn, Inc., Kitchener, Ontario. The Capstone course instructor is in charge of teaching project management tools and techniques during the first semester, and also acting as an overall Project Director, organizing project teams and assessing the groups' work against the standards that projects are expected to meet. In the first semester project teams define and begin their technical projects and in the second semester they do the majority of work and complete the projects. The position of technical advisor for each of the project groups is split among the EET faculty, based on the faculty member's area of expertise.

In the outcomes assessment process, the faculty teaching each course records how well the students do as a whole on the assessment, with a typical goal being "80% of the students achieve a score of 8 out of 10, based on the rubric used." In most courses, the outcomes are assessed individually, but in the Capstone course, with its emphasis on teamwork, some of the outcomes are assessed for the project team as a whole. At the end of each semester, the assessment information from all courses is tabulated by the program coordinator, and the EET faculty meets early the next semester to review the results. Of the outcomes that do not reach their goals, the faculty as a whole choose ones for closer study, and the faculty person teaching that course decides on corrective action to take the next time the course is taught. Such a feedback loop is our way of ensuring continuous improvement in the EET program.

The twelve Program Outcomes assessed in the Capstone course are: (EET graduates have …)

(b) an ability to plan, carry out, and evaluate a group project to solve a technical problem.

(d) an ability to apply creativity in the design of systems, components or processes appropriate to program objectives

(e) the ability to function effectively in teams both as a member and as a leader
(g) an ability to communicate effectively
(h) a recognition of the need for, and an ability to engage in lifelong learning
(j) a respect for diversity and a knowledge of contemporary professional, societal, and global issues
(k) a commitment to quality, timeliness, and continuous improvement
(l) the knowledge to manage change and improve productivity
(m) an ability to use the concepts learned in fundamental communication courses and posses more developed skills in research and writing in a discipline specific context.
(n) the ability to apply project management techniques
(o) the ability to use appropriate engineering tools in the building, testing, operation, and maintenance of electronic systems
(p) the ability to analyze, design, and implement industrial control systems, computer network systems, or electronic systems

Figure 1 shows the rubric used to assess a portion of Outcomes (m) and (p), which uses the final written report of the project team. The rubric assesses for Outcome (m) the ability to write in a discipline specific context, in this case writing a final report on the project. The rubric is also used as a part of the assessment for Outcome (p), the ability to analyze, design, and implement systems. The report's description of the team's design process, and inclusion of design process evidence, is a measure of how well the students understand the design process.

Outcome	Tool	Rubric	Superior	Excellent	Good	Fair	Poor
		A7	10	9	8	7-6	5-0
(m) … writing in a discipline specific context. and (p) … ability to analyze, design, and implement systems	Final Report	Document the Design Process	Design process completely detailed All appropriate supporting documents present in written report Clear understanding of design process demonstrated	Mostly detailed Most Mostly clear	Basically detailed Some Some-what clear	Sketchily detailed Few Little	Not detailed No Poor

Figure 1. Combined Rubric used to assess a portion of Program Outcomes (m) and (p) in the Capstone course

The entire assessment of Outcome (m) in the Capstone course also includes assessing the project proposal, status reports, technical information updates, and the Senior Design Conference PowerPoint presentation. Outcome (p) for each of the project groups is also assessed further by the course instructor and the project's technical advisor. These assessments are done using other rubrics not shown in this paper.

After the spring semester of 2009, the Capstone course assessment results showed that two of the program outcomes stood out as missing their goals by a large margin. Outcomes (m) and (p), with the seven project teams scoring an average of only 5.5 out of 10 on the rubric (Figure 1), were well below the goal of an 8 out of 10. The Capstone course instructor looked for reasons why these outcomes were so poor that year, and decided that what had changed in the course process was that a project webpage was not used by the project teams that year, as had been required in the past.

When the Capstone course instructor first began requiring project webpages for Capstone projects in the spring semester of 2005, the university used the WebCT course management system, which is now a part of Blackboard. At that time, WebCT's Student Presentation feature allowed the course instructor to set up teams within the software, and the teams could set up their own html-based Homepage and links to other information needed. The final written reports done by the students for 04/05 projects showed a marked increase in quality, especially with regards to documenting their design process. However, the Capstone course instructor did not gather specific evidence at that time to prove this assertion.

In the fall of 2008, the university switched from WebCT to the D2L course management system. The Capstone course instructor did not find any function within D2L that was equivalent to the WebCT Student Presentation feature. (D2L has a separate software package called ePortfolio, which would probably suit the purposes of a project webpage, but the university did not purchase that software option.) D2L does include a "Group Locker" function that stores files in a common location accessible only by the group and by the class instructor. Any member of the project group can upload files to the locker. For the Capstone projects 08/09, the course instructor decided that the group locker function would be sufficient for the function of saving and sharing project information, and required its use. The course instructor checked periodically during the year to make sure groups were using the lockers to store information needed by the project. However, in the locker there is no organizing structure available, as there is when a webpage and links must be maintained during the course of the project execution. So the group locker acted as a big box to throw papers in, where they were confused and then ignored. The final written reports for 08/09 were assessed as much poorer than the past years, in such areas as how well the design process was documented. Many of the final written reports did not even include documentation that was present as files in the group locker.

In the summer of 2009, with the poor results of the final written reports of 08/09 in hand, the Capstone course instructor searched for a way to reinstate the project webpages requirement. There are many types of software available for writing and maintaining webpages, and many commercial sites, that for free or a low cost, will host web sites. The course instructor did not like any of the options he investigated, due to the fact that commercial ads are present on most sites, that a true homepage/supporting links structure were often not clearly apparent, and that these webpages would have no real protection from harmful software attack.

Further research into D2L revealed the little-used (at least at this university) software feature called “User Homepages”. This feature is meant to be used as a Facebook-type self-introduction page by each student individually. It allows a homepage with links to supporting documents, with folders for those documents provided within D2L. But with some prior setup and organization by the course instructor, the User Homepage can be used as a group project webpage. In 09/10, a project webpage was again required for the Capstone course.

A rubric was developed to evaluate the project webpage use during the course of the project. This rubric was changed and updated as the year progressed, and no consistent data was gathered on group scores as the project progressed. That data will be gathered next year. The format of the rubric, as can be seen in Figure 2, is such that the course instructor puts in a checkmark to indicate the level of achievement of that particular item. This is done in order to reduce the instructor’s workload. Addition comments can be added at the end. The project group gets this filled-out rubric returned and they can see specifically what items are missing, or are insufficient, and can correct those problems.

EET 470/471 Capstone WebPage Rubric				
Project Name			Date Assessed	
These items are evaluated in the Formal Project Proposal – just need to be present				
	Present - 1	Not Present - 0		
Title Block (Names, etc.)				
Abstract				
Charter				
Formal Project Proposal				
PowerPoint from Conf.				
Need to be updated during project. If an item is not needed for this project, or is not required to be done yet, do not score it				
Reports	Excellent – 3 Updated on schedule	Good – 2 Missed 1 update	Fair – 1 Missed 2 or more updates	Not Present - 0
Gantt Chart				
Customer Reviews				
Status Reports				
Deliverables Table				
Justification Statement				
Technical Information	Excellent - 3 Up to date – matches project status	Good - 2 Behind by 1 date/revision	Fair - 1 Behind by 2 or more	Not Present - 0
System Diagram				
Links to similar projects				
Research List of webpages				
Other pictures/drawings				
Circuit schematic				
Links to spec sheets				
Enclosure drawings				
Parts list w/ Costs				
Software listings				
User’s Manual				
Total - % of possible points				

Figure 2. Project Webpage Rubric used in Capstone course

The requirements of webpage use are clearly defined for the project groups in documents available to them in the D2L page for the course. Appendix 1 shows a summary of the details of how the webpage process is used currently in the EET Capstone course. Appendix 2 shows an example of a final group project homepage from 09/10.

Data on the assessment of the final written reports were gathered at the end of the year 09/10, and compared to the past three year's performance, as seen in Figure 3. The data shows a clear drop in student performance on the portion of Outcomes (m) and (p) assessed by final written report Rubric A7 (Figure 1), for the year when a project webpage was not required, and a return to much better results when the project webpage requirement was reinstated. With only five to seven project groups each year, there is not a large enough data set to analyze and call this a statistically significant result, but common sense says it is a significant result.

Year	# of project groups	Project Webpage?	Assessment results from Outcomes (m) & (p), using Rubric A7. (average on a 10 pt scale)
06/07	6	WebCT Student Presentation webpage	8.2
07/08	6	WebCT Student Presentation webpage	7.8
08/09	7	D2L – Group locker use only	5.5
09/10	5	D2L User Homepage webpage	9.4

Figure 3. Four years of assessment data of a portion of Program Outcomes (m) and (p) from the Capstone course

The 09/10 results were also higher than in 06/07 and 07/08, but the capstone course instructor attributes that to a specific effort by the instructor that is probably not repeatable on a consistent basis. Because the final reports were so bad in 08/09, the capstone course instructor spent the year constantly reminding the groups to update their webpages and the importance of the final written report, to the point of "nagging" the students. Because a good process is back in place; a required project webpage, the nagging should not be required in future years. The results of assessment will be examined closely after the 10/11 year to ensure this is true.

In addition to the web page and final written report data assessment detailed above, the use of project webpages in Capstone student projects has had a few pitfalls, and many successes, which can be detailed as:

Pitfalls:

- The D2L User Homepage feature is an awkward system, being used in a way for which it is not intended. Students require extensive help from the course instructor when starting to use the webpages and creating links.
- If a student uses the D2L User Homepage function for this course, he/she can't use it for another course.
- In this 2-semester sequence course, the group locker files in D2L will not transfer automatically to the new semester. However, the students and/or instructor can make a

Zip file of the files in the group locker, download, and then upload the files to the new course.
- The project group member delegated the task to keep the webpage updated must be chosen carefully. Even if all the other team members are updating the group locker on a timely basis, none of that is apparent if the project webpage isn't updated.

Successes:
- Groups do not need to wait for a missing member of team, and any data that only he/she has, to continue work on the project.
- Students keep track of their researched technical information more readily when they have a place to save it to right away.
- Students will save more technical information when they can just save a file or a link to the project group locker, rather than having to print and save pieces of paper.
- Status reports are submitted and Gantt Charts must be updated on a regular basis, so students realize their progress or lack of progress.
- Tracking student progress is less time consuming for class instructor. The instructor checks webpages on Fridays every two weeks, and assesses them quickly using the rubric, which is much less time consuming than sorting through piles of paper submitted or following up on papers not submitted.
- The instructor can see if groups actually have the technical details that the Status Reports say they have.
- Although this is not assessed in a formal way, the course instructor believes that because all students in the Capstone course can see other groups' webpages, this produces positive peer pressure that improves the webpages overall.

Conclusion

Requiring a project webpage is an important tool for successful Capstone projects, as documented by improvement in assessment of specific Program Outcomes. The SDSU EET program is convinced that the use of project webpages is a good communication, project management, and project design tool, and will continue to require its use in the Capstone course.

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Byron Garry is an Associate Professor in the Department of Engineering Technology and Management in the College of Engineering at South Dakota State University, has been Coordinator of the Electronics Engineering Technology program since 2000, and has taught the EET Project Management/Capstone course since 2001.

Appendix 1. SDSU EET Capstone Webpage Process Detailed

Because of the software structure of the D2L User Homepage function, only one student in each group can make changes to the project homepage, but all members of the group can upload to the group locker. From there, it is one of the assigned roles of the project group to update files from the group locker, and to maintain the group webpage. The course instructor gets the specific URL address of the User Homepage from the project team member, and posts that address in D2L so all students in the Capstone course, including students on other project teams, can see the resulting webpage and follow the links.

The linked files can be in many of the software formats that are useful for the project, although D2L does not accept some kinds of files, such as Microsoft Project *.mpp files. The course instructor provides workarounds for the students, such as instruction in how to make a screen-capture snapshot of the MS Project Gantt Chart, and then insert the picture on the homepage, instead of linking to a file. D2L accepts:

- Word for proposals and status reports
- Excel for data collection and presentation
- PowerPoint for the team's Senior Design Conference presentation
- MS Project Gantt Chart screen snapshots (jpg) for project tracking
- HTML for the project homepage and for links detailing technical information
- JPG scans of technical catalog figures or pages
- PDF for all other types of files, including CAD files;

whatever is needed to detail the technical project.

The milestones that must be met for the two-semester Capstone project can be detailed as (with items marked with a (*) required to be on, or linked from, the project homepage):

- Choose team and project
- Write a *charter, and get the project approved
- Write a *formal proposal with specific project goals and deadlines
- Develop and update a *system diagram with *technical details proposed
- Maintain a *Gantt Chart that is updated as the project progresses
- Write *status reports and *customer reviews on the project's progress
- Produce a *PowerPoint and present at the Senior Design Conference at the end of the first semester
- Build and test a prototype of project/ *technical details updated
- Complete a *project review early in the second semester
- Build and test the final project / *technical details completed
- Present project at the Engineering Exposition at end of second semester
- Produce a *final written report

The course instructor provides in D2L an example project homepage for groups to see and/or emulate. This example page demonstrates minimum requirements; the students may do more. The instructor also posts the workarounds and specific software instructions needed to make the D2L User Homepage work for this purpose. The Capstone course instructor is not satisfied with the D2L User Homepage structure and workarounds required, and so is continuing to search for a better place to host the project webpages.

Appendix 2. **Example of a Project Group Homepage with Links to Subpages**

This homepage has been slightly reformatted to fit this portrait-orientation paper. The links, marked by an underline, are not active in the electronic form of this paper.

RFID Drink Dispenser

Project Team Members: XXX, YYY, ZZZ
Technical Advisor: XXX
Customer: XXX
Last Updated: 4/27/10

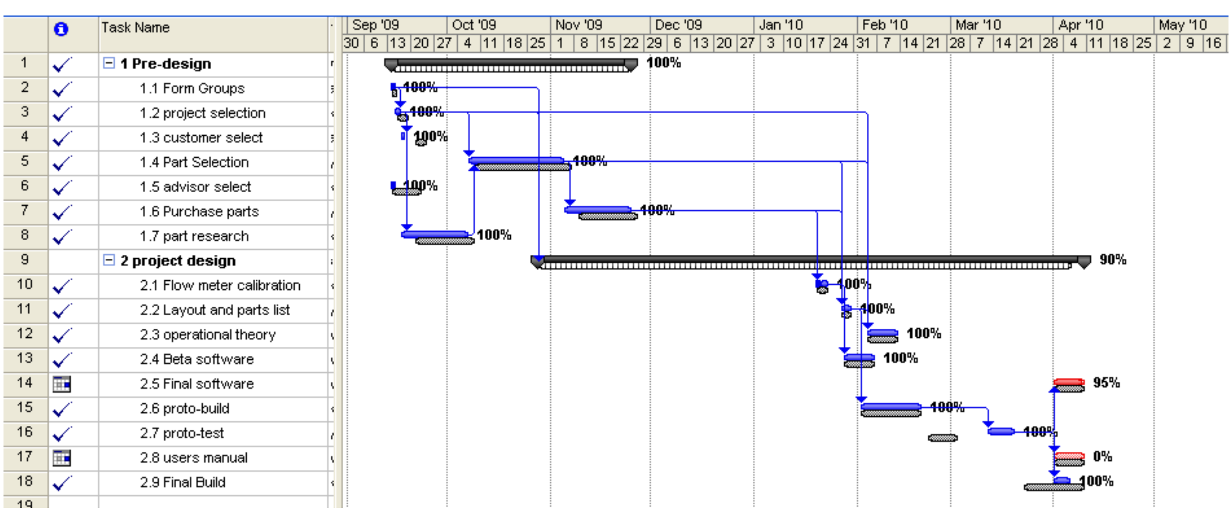
Abstract/Summary

Our project team designed and built a beverage dispenser capable of tracking quantities dispensed per individual using RFID tag identifiers assigned to them. This system will allow our customer to proportionally distribute costs to the individual users when they choose to settle their tab. We completed this project by April 10, 2010 for a cost of $240.00.

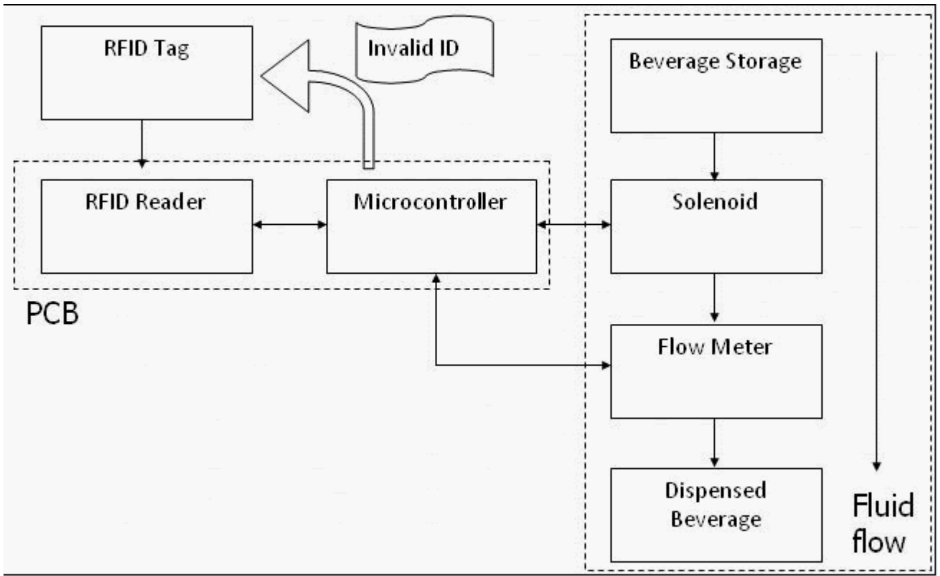
If this project was to be done in industry each of our 3 team members would be paid an hourly rate of $19.23 /hr. With each of the team members working 3 hours each week for the 27 weeks until completion the labor costs would reach $4672, for a total of about $5500.

Our system works by running the main software on a Basic STAMP microcontroller. A RFID reader will identify the individual using the system, and then allow that individual to dispense the beverage. The quantity dispensed will be tracked by a digital flow meter connected to the microcontroller. The microcontroller will have an array of the accepted RFID tags, when the tag is verified by the RFID reader; the microcontroller will output who used the system, what time they used it, and the quantity dispensed.

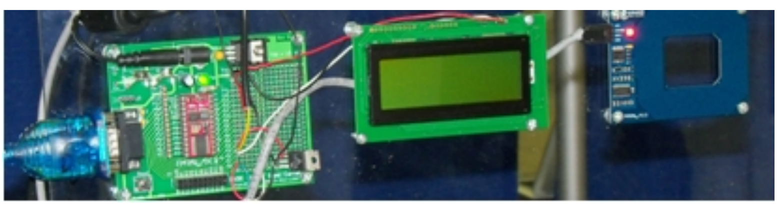
Gantt Chart



System Diagram

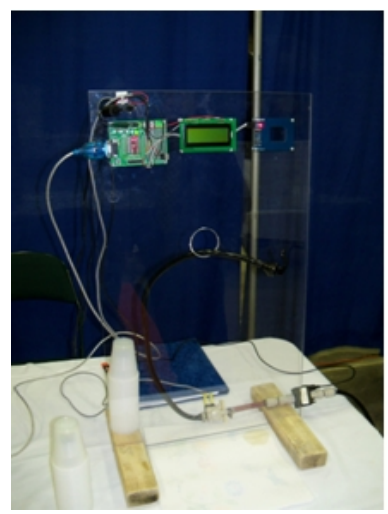


Final Project Pictures



BASIC Stamp module LCD Display RFID module

System mounted for display



Formal Documents
Formal Proposal
Powerpoint
Charter
Final Report

Data Sheets
Super Carrier Board
BS2e MODULE
RFID Reader
Flow Meter
Solenoid
TIP29
LCD

Other
Deliverables
Software Flowchart
Parts List
Schematic
User Manual
Final Code

Report/Review
Status Reports
Customer Reviews

Empowering Undergraduates to Design and Conduct Experiments and Attain Outcome 3b of the ABET Engineering Criteria

Beckry Abdel-Magid

Department of Composite Materials Engineering, Winona State University, Winona, MN 55987. Beckry@winona.edu

Abstract

Two approaches of incorporating design of experiments in an undergraduate laboratory course are presented in this paper. The first approach consisted of a semi-structured design of experiment project with prescribed experimental procedure, and the second approach consisted of an open-ended design project where students had to develop, justify and execute an experimental program. Comparison and contrast between these two approaches are presented in this paper. It is shown that while the second approach is rather daring and time consuming for both faculty and staff, it has more potential to provide a better learning experience to students and help them attain all the elements of EAC-ABET Outcome 3b.

Introduction

Outcome (b) of criterion 3 of program outcomes specified by the Engineering Accreditation Commission of ABET states that students should attain "an ability to design and conduct experiments as well as to analyze and interpret data". The outcome consists of four elements: designing an experiment, conducting an experiment, analyzing data, and interpreting data. The last three elements can easily be addressed in a typical engineering laboratory course, where students follow prescribed procedure to run the equipment, test specimens, obtain results, analyze data and write a report in which they discuss and interpret the data and draw conclusions. However the first element of "designing an experiment" is rather difficult to address in an undergraduate course. The difficulty is due to many reasons including lack of time to cover essential laboratory tests in the curriculum, lack of preparation of undergraduate students to design and perform their own experimental work, and the extra training needed to operate expensive equipment.

Some educators argue that it is better to have students run fewer but more open-ended experiments than many well-prescribed and guided experiments [1]. This paper describes two attempts in implementing open-ended experimental assignments. The first attempt was made using a prescribed and semi-structured experimental program in an effort to help students and provide them with step-by-step procedure to meet the project objectives. This approach was taken to preserve the number of thirteen experiments that are usually performed in one semester.

The second attempt was made with no prescribed experiments to allow students to decide on the type and number of experiments to perform and achieve their goal. Students were given three weeks to complete their projects and the number of assignments per semester was reduced to ten. The two methods used and the observed student performance are detailed in the following paragraphs.

Definitions and Clarification

In the context of this paper, designing an experiment entails determination of properties needed to meet a given objective, selection of experimental conditions, specifying required data, type of tests and number of specimens, and planning the data analysis. The data analysis typically includes determination of experimental error, consistency of data and validity of test results. This definition differs from the broader field of statistical design of experiments in the sense that students are not expected to perform comprehensive cycles of investigation that involves comparison of various treatments and empirical studies with factorial designs [2]. Such topics of industrial design of experiments are typically covered in a separate elective undergraduate or graduate course.

Semi-Structured Design of Experiment Project

In this project students were asked to design and conduct a set of experiments to prove that flexure testing of materials can be used to determine flexure properties as well as tensile and compression properties of the materials. They were also asked to find an empirical correlation between the flexural modulus of unidirectional composite materials and the tensile and compressive moduli along the fiber direction of the material. The complete project assignment is shown in Appendix A.

The project was assigned in the third week of the course after the syllabus was introduced, preparation of laboratory reports was explained, and samples of previous reports were discussed. In addition students had completed two experiments in which the topics were discussed in class, and students performed the tests, analyzed the data and submitted a report on each experiment. The reports were graded and each student received feedback on her/his report.

The project statement included guidelines for students to determine the tensile properties, compressive properties, and flexure properties, and to find a mathematical expression relating the tensile, compression and flexure moduli. Samples of the material including tensile specimens for tensile tests, compression test, and flexure test were prepared and provided to each group of students. The theoretical background of the tensile, compression and flexural behavior and properties of unidirectional composite materials was covered in the lecture part of the course. An equation relating the flexural modulus to the tensile and compression modulus was also discussed in class. In addition, ASTM standards, testing procedure, and instrumentation of specimens for these tests were covered in the lecture part of the course [3-5]. A flowchart showing the various components of the project and the tasks performed by students is shown in Figure 1. More explanation of alternative laboratory assignments is given in Reference [6].

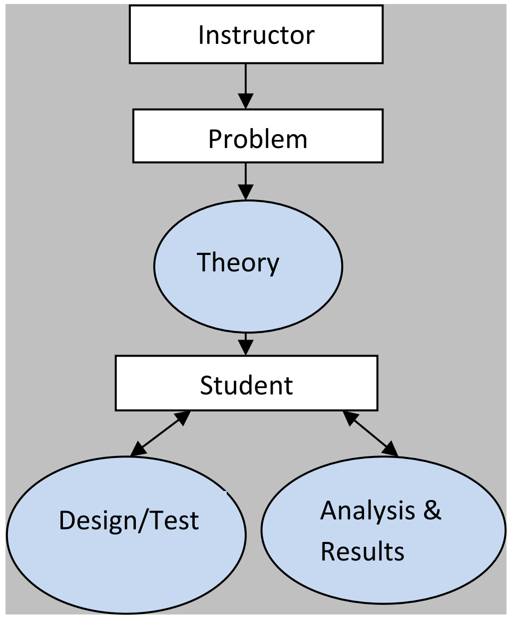


Figure 1. Problem, Theory and Execution in a Semi-Structured Design of Experiment Project

Three laboratory sessions were dedicated to the project and each session was dedicated to a specific test (tension, compression, and flexure) to guide the students through instrumentation and use of equipment and fixture for each test. ASTM standards for each test were also given to student groups. From the theoretical background and guidelines given in class, it was obvious to student groups what tests to include in their design of experiments and what properties to determine from each test. The only part that was not obviously clear was the failure analysis of the flexure specimens to determine which specimens failed in tension and which failed in compression. But by the end of group brainstorming, the majority of student groups included failure analysis of the flexure specimens in their design.

Observations: Though initially intimidated, students were excited at the prospect of designing and conducting their own experiments. However the excitement faded away as the steps to carry out the project unfolded in the usual regimented manner of going to the lab at a certain time and be guided and closely watched throughout the test procedure. In addition to realizing that the experimental design steps were already laid out for them, and that clear instructions were given to perform each test, students realized they had to follow a structured program, conduct each experiment separately and that all groups had to perform the same tests. There was not much room for independent exploration or creativity. The only remaining challenge was to analyze the data and develop a relationship between the results of the three experiments. But by the time student groups came to analyze data from the three experiments and summarize their findings, a number of students seemed to be disengaged from their own design and plans.

Students worked in groups in all phases of the project including data analysis and discussion of results, but each student was required to submit her/his own design report. The design reports showed that less than a third of the students were able to follow their design plans, make good correlation between the results of the three experiments, and establish an empirical relationship between the flexure modulus and the tension and compression moduli. About one third of the students had a fairly good understanding of the objectives of the project but failed to provide a coherent relationship between the results of the three experiments. The majority of the students, however, seemed to have lost ownership of their design, they could not see the connection between the three experimental components of the project, and they treated each experiment as a separate project. Moreover their reports indicated that they were more confused to the point of not understanding the results of each experiment. Assessment of student performance in the project indicated that the project did not have a positive effect on learning the elements of design of experiments and interpretation of data for the majority of students. This prompted a return to the single test format and a search for an alternative format to enhance student learning of how to design and execute a laboratory experimental program.

Open-Ended Design of Experiment Project

In this project students were asked to design experiments to identify and qualify composite materials for specific applications. Given the application, e.g. skis or boat hull and proposed materials by suppliers or fabricators, students were asked to determine the required properties for the specific applications, design experiments to find the constituents of the proposed materials, determine the required properties, fabricate specimens according to ASTM standards, conduct experiments, analyze data and provide results and recommendations. A sample of the assigned project is given in Appendix B.

The project was assigned in the third week of class with a due date at the end of the semester. Student groups were allowed to work at any time as long as they could ensure availability of equipment and coordinate with the laboratory technician if they needed any help. In addition, the last two laboratory sessions of the semester were dedicated to working on and finalizing the project. The majority of the experiments that could be used in the project were covered in the regular part of the course. Student groups were asked to submit a proposal and discuss their design and plans before implementation. The flowchart of the project is shown in Figure 2.

Three different projects were assigned to seven groups of three students each. Two groups worked on the first project, two on the second, and three on the third project. A sample of the projects is shown in Appendix B. Each group submitted a brief design proposal and plan. The outline of the proposal was discussed with the instructor to ensure that the given material is sufficient to perform all the proposed tests and that the general plan is sound. Since no guidelines were given, students felt more empowered to design and modify their own plans, and decide on what actions to take. The forensic aspect of finding the constituents and contents by weight or volume of the proposed materials added more intrigue and excitement to the project.

Discussion with groups revealed that each group employed a collective thought process to independently formulate the problem to find the performance requirements for each application. That is, what type of forces, stresses, strains, or environmental conditions would the material or component be subjected to for a given application; and what data are needed to evaluate the performance of the proposed materials under these conditions. The proposed project included determination of the tests needed to obtain these data; and project plans included conducting tests, finding results and making recommendations.

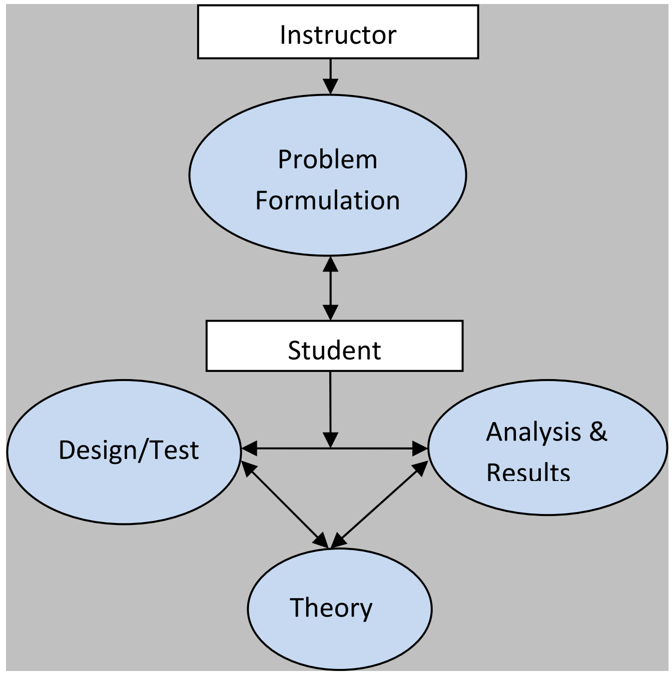


Figure 2. Problem Formulation and Execution in the Open-Ended Design Project

Observations: Traffic during office hours increased as students came in groups to ask questions and discuss their plans and methodology. The laboratory technician was constantly busy answering questions and helping with equipment setup. Other faculty in the department were not spared either. Students had high energy and excitement in taking matters in their hand. They went beyond what was covered in the course and conducted experiments they learned in other courses using proper standards and procedure. Unlike in the semi-structured approach, each group submitted a single report, and the quality of the reports was much improved from the individual reports submitted in the previous approach. Peer evaluations of group members were generally positive indicating full participation in all phases of the project. In addition to engagement and enhanced teamwork, students also exhibited a sense of accomplishment and responsibility in following through with their design, modifications, and recommendations. Similar observations were made by Sheppard et al. [6].

Notes taken during the project and after grading and student feedback included the following measures to improve student performance:

(i) Discuss the design proposal with each group at length, and give feedback on modifications made by students
(ii) Provide a separate rubric for the design report
(iii) Provide a sample design report for students to discuss and critique

Conclusions

Two approaches for design of experiments were used in an undergraduate engineering course. The first consisted of a semi-structured design project and the second consisted of an open-ended design project. The semi-structured approach guarantees safety in the laboratory and economy in time and resources. However, it was observed that an overly prescribed experimental project alienates students by giving them a false sense of autonomy in designing and conducting experiments. Student performance in such a project did not show a significant improvement from the traditional rigidly prescribed experiments in learning the concept of experiment design. On the other hand, the open-ended project approach is more demanding of faculty and staff time, but it promotes engagement, teamwork, creativity, and a positive student attitude toward designing a scientific laboratory investigation. It is observed that this approach empowers students to attain the four elements of outcome 3b; namely an ability to design and conduct experiments as well as to analyze and interpret data.

Acknowledgement

Mr. Jerry Johnson, Senior Engineering Aide at the Department of Composite Materials Engineering, was instrumental in preparing for and helping students with the project. Student feedback on the project assignment is highly appreciated.

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Biographical Information

Beckry Abdel-Magid is professor and chair of the Department of Composite Materials Engineering at Winona State University, Winona, MN.

Appendix A

Sample of Semi-Structured Design of Experiment Project

Problem Statement
3-point and 4-point flexure tests are used to determine the flexural properties (strength and modulus) of reinforced composite materials. They are also sometimes used to determine the tensile or compressive properties of these materials when higher capacity testing equipment is not available. Two objectives are required in this project. First, to use ASTM Standards to determine the tensile, compressive and flexural properties of an IM7/8551 unidirectional composite material. Second, to find a relationship between the flexural properties and the longitudinal tensile and compressive properties of the unidirectional composite. It is also required to find a mathematical expression for the flexural modulus in terms of the tensile and compressive moduli in the longitudinal direction.

Material
Hercules IM7/8551 carbon fiber/epoxy unidirectional composite material.

Properties to Be Determined
1. Tensile Properties: stress-strain curves, ultimate strengths, ultimate strains, and moduli in the longitudinal direction (σ_{LU}, ε_{LU}, E_L) and in the transverse direction (σ_{TU}, ε_{TU}, E_T), and the Poisson's ratio in the longitudinal (ν_{LT}) and transverse direction (ν_{TL}).
2. Compressive Properties: same as above except for Poisson's ratio.
3. Flexural Properties: stress-strain curves and flexural strength σ^f_u, ultimate flexural strain ε^f_u and modulus E_L^f.
4. A mathematical relationship between the longitudinal moduli E_L^T, E_L^C and the flexural modulus E_L^f.

Deliverables
A Report Showing:

Project Title Page
Table of Contents

Introduction:	- a description of project and objective
Procedure:	- a brief procedure for each test
Results:	- provide data and at least one graph of the results for each test.
	- provide mean, std. deviation and cov for each property determined.
	- provide precision and bias analysis according to ASTM Standards.
	- provide strength envelopes for the material.
Discussion:	- discuss results of each test commenting on properties and mode of failures.
	- discuss relationship between the flexural properties and the tensile and compressive properties.
	- provide a mathematical equation for E_f in terms of E_{TL} and E_{CL}, and compare with relations from the literature.
Conclusions:	- provide the major findings in your study.

General Rules

1. Each group is responsible for its results in terms of accuracy, description of failure mode, and problems during testing.
2. Results from both class sections should be posted by Thursday of each week.
3. Individual reports are expected from each student one week after the last experiment.

Appendix B

Sample of Open-Ended Design of Experiment Project

Purpose: A boat and marine structures company is seeking to improve the performance of its boat hull by using the attached composite materials panel. The panel is recommended by a composite materials manufacturer. The boat and marine structures company would like to know the materials used in the panel, and the properties of the material as required for use in a boat hull.

Objective: Design a set of experiments to find the materials used in the panel. Determine the required properties needed for the application. Make specimens and test them to determine each property.

Deliverables: A report indicating:

1. Tests used to find panel materials
2. Type and shape of materials used in the panel (fiber and matrix, fabric, etc)
3. Constituents contents (fibers, fabrics, layers, matrix, etc)
4. Properties needed for the desired application with explanation of why these properties are selected
5. Samples used to find the properties
6. Values of these properties
7. Conclusions and recommendations

Evaluation:

1. Design of test program to investigate materials and properties
2. Preparation of specimens
3. Testing and results
4. Discussion of results, conclusions and recommendations
5. Quality of report

The GasDay Project at Marquette University: A Laboratory for Real-world Engineering and Business Experiences

Thomas F. Quinn, Ronald H. Brown, and George F. Corliss

Department of Electrical and Computer Engineering
Marquette University

Abstract

This paper presents Marquette University's GasDay Project, a research activity that has been developing natural gas demand forecasting models since 1993. The project provides students with opportunities for research and employment, and serves as a major technology transfer center at Marquette by licensing software and forecasting models to energy companies across the United States. The project is part of the College of Engineering's Department of Electrical and Computer Engineering. Participants range from high-school age through graduate doctoral students; most are Marquette Engineering students, with several students coming from other disciplines including Mathematics, Computer Science, and Business Administration. These students produce an engineered, licensed product used by natural gas utilities throughout the United States to forecast over 20% of the United States daily natural gas demand.

Introduction

Collegiate engineering programs strive to prepare students to become successful engineers who are prepared to enter a workforce that badly needs them. A common experience for newly hired engineers leaving the classroom and lab behind is to bump into the reality that the best engineering decisions are not always the best business decisions, and vice-versa. Issues of cost, scalability, competitiveness, and others often force compromises into what might otherwise be the most elegant engineered solutions possible. An engineer new to the workplace might feel a bit disillusioned seeing how solutions are designed to meet multiple, often non-technical, objectives.

There's also the thorny matter of customers with their own wants and needs, their own business objectives, and their own varying levels of competency and available technical support – messy issues that don't often intrude into an engineer's education. Delivering and supporting engineered products into customers' hands to generate value for their businesses can require some skills that an engineer may not have encountered in college.

College engineering programs offer several enhancements beyond the classroom to help prepare engineering students for workplace realities. The most notable of these are co-operative (Co-op) engineering programs, and there are many other forms of internships, industry-sponsored research, and various other university-industry collaborations that help young engineers learn to apply their new skills at work. This paper describes a project that offers students the opportunity for paid engineering work right on campus, on a university-licensed software product.

GasDay Project Overview

Marquette University's GasDay Project licenses a natural gas demand software application to 24 natural gas utilities around the United States. On a typical day GasDay software installed at those utilities forecasts over 20% of the nation's natural gas demand. The models and software application are developed by undergraduate and graduate engineering students at Marquette, under the supervision of faculty members and a business manager.

The GasDay Project was begun in 1993 by Ronald Brown, Ph.D., as a research project funded by the Wisconsin Gas Company. Additional funding came from the Wisconsin Center for Demand Side Research, and then from the Gas Research Institute (GRI), a natural gas industry collaborative. That effort produced promising research results and the first forecasting models, which were put into use at the Wisconsin Gas Company in Milwaukee, WI (now part of We Energies). After a brief partnership with an outside firm, Marquette began licensing GasDay directly to natural gas utilities in 2001.

The GasDay Project is not the result of a strategic plan to enter into a retail software licensing business. Rather, it is the result of an unexpected end to a more typical university-industry technology transfer arrangement. Once the first GasDay model was in use at Wisconsin Gas Marquette University realized it had a licensable property. The university found a very large, international energy consulting business as a commercialization partner. The partnership was successful: GasDay forecasting tools were licensed by several utility companies. Unfortunately Marquette's partner ended up declaring bankruptcy due to problems in unrelated businesses. One result of that bankruptcy was that company's exit from the business that marketed GasDay.

That development left five natural gas utilities that had come to depend on GasDay without a solution. Each utility requested that Marquette establish a software license with them to assure uninterrupted service, which the university did, and Marquette GasDay was underway. As this licensing activity grew Brown staffed the GasDay Lab with graduate and undergraduate students who participated in his research and worked to expand and deliver GasDay.

Today Marquette University's GasDay Project is one of the largest research and technology transfer activities at Marquette. It remains within the Department of Electrical and Computer Engineering, part of Marquette University's College of Engineering. GasDay is self-funded from licensing revenue and research grants. The revenue generated by the project provides Marquette undergraduate and graduate students with opportunities for research, financial aid, and hourly employment. GasDay revenue also generates royalty income for Marquette.

GasDay Project Activities

The GasDay Project's activities provide the following contributions to Marquette:

Research Laboratory – the GasDay Project conducts ongoing research into energy demand and modeling techniques. This provides a rich and contemporary set of topics for graduate student research towards master's theses and doctoral dissertations. Research is funded by direct sponsorship of industrial partners and by GasDay product license fees. The results of this research are disseminated as licensed software and research reports for our customers and as more traditional academic journal articles and conference presentations.

Educational Laboratory – the GasDay Lab regularly hosts course-affiliated student projects, providing students the opportunity to work directly with some of the largest energy companies in the United States. Many projects are from the College of Engineering's senior design program, where a team of students work for a full academic year on a project of direct interest to a GasDay industrial sponsor. Other courses with students undertaking GasDay projects come from the College's Engineering Management program and from the department of Mathematics, Statistics, and Computer Science. Approximately fifteen students participated in four GasDay Lab student projects over the last academic year.

Technology Transfer Center / Student Employment Site – Marquette University licenses GasDay software applications and mathematical forecasting models to energy companies. Marquette students participate in all aspects of this business, including software development and testing, data analysis and modeling, marketing, and customer support. This activity has the benefit of generating significant revenue used to fund excellent hourly work opportunities and graduate student support.

Over the last academic year the GasDay Project provided the following student financial support:

- assistantships for five graduate research assistants in the College of Engineering and one from the Department of Mathematics, Statistics, and Computer Science
- hourly employment for one graduate student and thirteen undergraduate students from the College of Engineering
- hourly employment for one high school student participating in Marquette Engineering Outreach programs, who plans to study engineering in college

Industrial Outreach Center – Over the course of a typical year, the GasDay Project interacts with approximately thirty companies working in energy or related industries. We conduct on-site visits and teleconferences, and we host several companies who visit Marquette University. GasDay also helps organize the Gas Forecasters Forum, an industry conference held each fall as part of the Southern Gas Association's Fall Leadership Conference.

Licensable GasDay Technologies

GasDay licensable technologies are the result of the commercialization of GasDay's laboratory research. Students are involved in every step of this process – from participating in the research, to implementation and test of new features, to final delivery and customer support activities.

Marquette University licensed GasDay products include:

GasDay - Marquette University's flagship energy forecasting technology. The GasDay family of technologies includes GasHour, GasMonth, the Additional Weather Inputs model enhancement, and other application enhancements and services.

Measurement Scene Investigator (MSI) – a data analysis tool used by utilities to detect errors in the reporting of natural gas flow to large industrial and commercial customers.

Heating Oil Consumption Forecaster (HOC) – a GasDay tool licensed to heating oil companies to aid in delivery planning. This tool can be generalized to support any business involved in non-continuous delivery of energy.

The GasDay Annual Business Cycle

There is an annual cycle to the business of GasDay that makes it well-suited for student participation. Not surprisingly, this cycle is based on the timing of the heating season in North America. Natural gas utilities spend the summer and early fall each year preparing for the upcoming heating season. So does GasDay. The fall is the busiest time of year at GasDay as students prepare software deliveries for our gas utility customers.

Research activity that leads to new model development ideas is ongoing, but each fall GasDay prepares a significant software release timed to coincide with the onset of the heating season. Early each spring, faculty and students jointly determine which model improvements to implement in GasDay product software, and work begins on that. At the same time, a separate team of students develops a work plan for software implementation of the features and improvements for the fall release. The combined teams set milestone dates for intermittent Alpha and Beta releases, software testing, integration testing, and mock customer deliveries for practice. All this work culminates in deliveries of new GasDay configurations sent out to customers throughout the fall season.

Every GasDay delivery is a custom configuration specific to a utility's natural gas distribution system. Most utilities are comprised of multiple energy distribution regions, or *operating areas*. GasDay students train custom models for each individual operating region and then merge those models with the current release of GasDay application software. Every integrated configuration is tested and packaged for installation at the customer site.

GasDay Model Improvements

The subject of most graduate students' research is related to improvements to the GasDay forecasting models, or the various treatments of the data used to train those models. Some example topics include:

- investigations into methods to build forecasting models for non-stationary systems
- an investigation into improved techniques to disaggregate monthly data into daily using correlated data (temperatures)
- improved detection and treatment of outliers in natural gas daily or hourly flow time series data
- ensemble techniques for combining multiple forecasts
- consider goodness-of-fit measures on various types of unusual days or derived from business costs
- model frequencies of unusual weather events

- exploitation of high-density weather measurements and forecasts

Ideas developed in student research that provide measurable, consistent improvements to GasDay demand forecasts are implemented each year in the GasDay product. This requires two implementations: a reference implementation in MATLAB that demonstrates the improvement across a wide variety of data sets; and a production implementation in the GasDay C++ model library that is shipped with the GasDay product. During final product testing, before release to manufacturing, the GasDay library results are compared to results generated by the MATLAB reference implementation to an accuracy of 10^{-9} across a large number of data sets.

In this way, a student in a two-year Master's degree program might see an idea from conception through to product implementation and delivery to a customer during her graduate school career.

GasDay Software Product Development

GasDay's software development team is led by a recent graduate of Marquette's Biocomputing program, who chose to join GasDay as a full-time employee upon graduating. The decision to hire a staff member to supervise this team helped to overcome problems caused by the frequent turnover of staff. The software development team tends to be staffed by undergraduate students majoring in Computer Engineering, Electrical Engineering, Computer Science, or Biocomputing.

GasDay software development is typical of many software product activities, pursuing two agendas:

- Software defect repair is year-around work, performed by all members of the team, old and new. Defects reported by customers or in-house testers are logged into an automated issue management system used by the team lead to manage the workflow of each assignment from investigation through to final test and resolution.
- New product / feature development is concentrated in spring and summer, though some form of product enhancement is always taking place. This work is driven by requirements captured by all GasDay team members using an issue management system and product development wiki.

GasDay's software development processes introduce students to many of the tools of the professional programmer and mandates use of many of the practices students encounter in their *Software Engineering* coursework. Elements of the software development teams practice include:

- Agile software development techniques, including frequent deliveries of working software, pair programming, team review, and test-driven development.
- Frequent collaboration with GasDay customers to improve application usability or to develop new feature ideas. GasDay is very fortunate to have a set of customers who agree to install Beta-version software to evaluate and test new features as they take shape.
- Tools for requirements management, issue management, and automated testing and test reporting.
- Software configuration management tools for change control and managed releases.

GasDay student software engineers get to participate in early-stage idea development through to feature implementation and release to customers. Participation in GasDay software development reinforces the importance of a disciplined and collaborative team approach and gives students an early opportunity to embrace techniques being taught in the classroom.

GasDay Data and Manufacturing Team

The *Data and Manufacturing* team are the GasDay members who manage and execute GasDay customer deliveries and follow up with customer support. Member of this team range from GasDay's very newest students to some of the project's most experienced graduate students.

At the start of the fall delivery season, sub-teams teams are assembled and assigned a set of customers with individual GasDay delivery dates spread out over several weeks of the fall. Each of these teams is responsible for receiving and managing the data that customers send to the lab for new model training, using the following process:

1. A student contacts the customer to establish delivery dates. Customers already have an expectation that new models and software will be delivered to them. The customer uses an automated tool to transmit data to the GasDay Lab.
2. A student generates a "data suspects report" that is reviewed with GasDay faculty, and used to work with the customer to correct errors.
3. Once data is cleaned a student will submit a job to GasDay's compute cluster for model training. This processing typically requires one to three days, depending on the number of customer operating areas and length of historical time series data.
4. Students merge the newly generated models with the current GasDay software release.
5. The new GasDay configuration is tested by multiple student team members, according to test processes documented in the project wiki.
6. A Microsoft Windows installer is created and tested on a computer that matches the customer's versions of Windows and Microsoft Office. GasDay IT Support students are tasked with making sure each Windows system configuration is available for this testing.
7. A GasDay configuration that has passed all stages of testing is uploaded to a secure FTP site for customer retrieval.
8. Students from that customer's manufacturing team will contact the customer to alert them to the installer's availability, and assist with installation and any other issues or questions.

Each team is led by a graduate student who usually knows the customer they are working for. Other members are newer graduate students learning the processes and younger undergraduate students who are learning the basics of how the GasDay Project works. Everyone participates, and much of the work is done in pairs to facilitate learning and catching errors.

The senior GasDay team members who lead these data and manufacturing activities serve as project managers and subject matter experts. Because of the rapid turnover of GasDay members to co-op employment and graduation, the structure of these teams serve to continually train up newer members into more complex roles. Another benefit of pairing undergraduate and graduate students as collaborators is that it provides undergraduate students a view of what it means to be a graduate student and to consider that as an option for themselves.

IT Support and Business Operations

Two other areas providing interesting work experiences are supporting the significant computing environment of the GasDay Project and participating in the business operations of the project.

Marquette University provides excellent IT support and basic management of our computer systems; however, the GasDay Project compute environment is customized enough that the project requires at least one student, and often two, to maintain all equipment and software. A very common task is to equip a new or refurbished computer system with a standard GasDay software configuration so that any student on any of the teams can log onto that computer and find all the tools they need. Interspersed with this are typical occasional failures of power supplies, hard drives, and other components. Students on the GasDay IT support team are able to replace failed parts, secure rebuilt systems, restore missing data, and reconnect to GasDay network resources.

GasDay also tries to maintain at least one student on staff to assist with the business of GasDay. Typical tasks for this role include generating license renewal notices, assisting in proposal development, developing marketing materials, and small project management. This role is often filled by a student from Marquette's College of Business Administration.

New Student Development

There is a tremendous learning curve when joining GasDay. A new team member must absorb a great deal of information about natural gas as a fuel, energy industry concepts, GasDay's role in that industry, and countless details about the data, methods, and results that are central to the product's function.

The most typical entry point for a new team member is to join the data and manufacturing team. Almost immediately, a new team member is able to put their basic MATLAB skills to work processing customer data or providing assistance in one of the many ongoing research activities. Students who have the best experience at GasDay are the ones willing to dig into an assignment and get comfortable working under the direction of a graduate student or faculty member.

The GasDay Project has several weekly structured meetings that new team members are expected to attend. This participation helps accelerate members' contributions to the project.

- The weekly *LDC Meeting* is a review of each GasDay licensee and any open issues or pending work they may have. It is at this meeting that teams are formed and assigned to each issue, or, during the fall delivery season, to the building and configuration of each utility's deliverable. New team members quickly become acquainted with each of the GasDay licensees and the particularities of their model or application.
- A weekly *Manufacturing and Development* meeting is a setting for topics related to new process ideas, improvement of existing processes, overall scheduling and planning, and special project development and discussion. This meeting has become a very valuable forum for students to identify obstacles or shortcomings in how they perform their jobs, and for the team to collaborate on ideas for improvements.

- *GasDay Camp* is an intensive series of hands-on sessions where new team members are led by a faculty and graduate students through the GasDay customer experience, from downloading and installing a new GasDay configuration, to running daily forecasts, and diagnosing common issues. This is where new team members learn about natural gas industry basics and the business motivations that lead a customer to value a product like GasDay.

Early in the project's history it would take at least a semester, and sometimes two, for a new team member to find a way to contribute and become productive. Over the years it has become obvious that the best mentors to new team members are the existing team of graduate students, who take the lead in organizing and overseeing most student orientation activities. Now a new student joining the project at the start of the fall semester becomes a key contributor to some of the GasDay configurations tested, built, and delivered later that same semester.

GasDay Project Challenges

GasDay's "academic" staff is its students and two faculty members. Administrative staff includes a business manager, a software team leader, and an administrative assistant. The majority of project workers are students, whom it is our mission to graduate to a career outside Marquette. This poses some significant obstacles to ongoing operations in a business developing a complex, engineered product customized for customers across the United States.

A typical student will start working for the GasDay Project at the start of their Marquette career: when they enter either as a freshman undergraduate or new graduate student. Undergraduate students have less background and experience to bring to the project, but are often able to spend four years working on the team. Graduate students usually will have a richer background to draw from, but most are master's degree students, and will only have a two year career. Everyone starts out at about the same level of ability, with some classroom knowledge, but little work experience. This represents GasDay's two significant staffing challenges: inexperience and frequent turnover.

As in most workplaces the best method to manage this challenge has been to grow strong contributors into leadership roles where they are able to mentor and develop newer team members. The less we try to force assumptions upon the team about who fits where based solely on age or class year, the more each student rises to their own level of competence and leadership. It is not unusual to see a junior-year undergraduate student teaching and directing the work of a new graduate student, or a second-year master's student teaching manufacturing team processes to new freshman at GasDay Camp session. As much as possible every GasDay role is described on the project wiki as a pair or team activity, so that there is always the opportunity for new team members to observe advanced GasDay activities at the side of a more experienced student.

A typical university is not an ideal home for a software product business. While many elements of a successful business are present, it takes careful management and planning to combine them into something sustainable. Some elements of a software business that were foreign to typical university business operations include price quotations and negotiations, invoicing processes, individual licensing of custom products, and participation in industry trade shows, to name only a few. Fortunately the various Marquette University departments involved with each of these items have been very supportive and flexible, and have invested the time to develop repeatable processes that lead to predicable results.

Conclusion

This paper has described Marquette University's GasDay Project, a working software product business that provides undergraduate and graduate students the opportunity to apply their classroom learning in a real, functioning business environment. Some of the benefits to students are:

- Hands-on learning in a business setting with real-world consequences for successes and failures
- Direct contact with customers and other industrial partners, and opportunities to teach them how to use GasDay and learn from them and their experiences with the product
- Experience with project management and the importance of working in a setting with competing priorities that must be met with a fixed set of resources
- Knowledge of how research is conducted, and the process to take it from the laboratory to the marketplace
- Immediately relevant career skills
- Financial support in the form of hourly salaries or research assistantships

Students leave the project with genuine work experience, letters of reference, and the experience of having participated in the larger setting of the College of Engineering beyond the classroom.

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Biographical Information

THOMAS QUINN, M.S. is the business and customer relationship director for Marquette University's GasDay Project. Mr. Quinn manages GasDay sales and licensing activities. He has also worked to bring new GasDay Project research to market as licensable technologies for the University.

RONALD BROWN, Ph.D. is an Associate Professor of Electrical Engineering and the GasDay Project's founder and chief scientist. In his GasDay work Dr. Brown has supervised the work of over 100 graduate and undergraduate students. Dr. Brown is a regular invited speaker at energy industry meetings and conferences.

GEORGE CORLISS, Ph.D. is a Professor of Computer Engineering and contributing senior scientist with the GasDay Project. Dr. Corliss has adapted GasDay model technology to two new applications under license to energy companies. He is an active participant in the lab's research and industrial partnerships.

ENHANCING STUDENT ENGAGEMENT IN INDUSTRIAL ENGINEERING PROGRAM

Dr. Swaminathan Balachandran
and
Dr. Justin Kile
Dept. of Mechanical and Industrial Engineering
University of Wisconsin – Platteville
1 University Plaza, Platteville, WI 53818

ABSTRACT

The paper provides an introduction to the industrial engineering (IE) program at UWP and the Pioneer Academic Center for Community Engagement (PACCE). The paper summarizes how student engagement has become larger in scope and now comprises of enhancing learning through service learning activities. The initial motivation for increasing student engagement in the industrial engineering program was to satisfy the criteria for accrediting engineering programs by the Accreditation Board for Engineering and Technology. The more recent development is the establishment of PACCE at UW-Platteville. The paper presents a summary of PACCE service learning projects and student reflections.

INTRODUCTION TO IE PROGRAM AT UW-PLATTEVILLE

The College of Engineering, Mathematics, and Science consists of seven departments: Chemistry and Engineering Physics, Mathematics, Civil and Environmental Engineering, Electrical Engineering, Computer Science and Software Engineering, General Engineering, and Mechanical and Industrial Engineering. The College has over 1700 student majors enrolled in ten degree programs. Bachelor of Science degrees are offered in chemistry, mathematics, civil engineering, electrical engineering, environmental engineering, industrial engineering, mechanical engineering, software engineering, engineering physics, and computer science.

The College's objective is to ensure that its students gain the knowledge and develop the mental skills, attitudes, and personal characteristics necessary to become successful citizens and professionals who can meet the present needs of business, industry, government, society, and the more demanding requirements of the future. Therefore, curricular requirements provide a strong foundation in the student's major field of study, supplemented by a broad background in the social sciences and humanities. Many courses that can fulfill the requirements in humanities and social sciences are available through UW-Platteville's study abroad programs. In addition, technical courses counting towards a degree at Platteville can be taken at our international partner institutions in Australia, Ireland, Norway, Germany, Sweden, and Turkey.

The College offers informal cooperative education programs for qualified students. The co-op programs are designed to integrate classroom studies with practical professional experience in a planned arrangement of alternate work assignments and campus studies. Through this coordination of formal study and practical work, participating students enhance their ability to relate theory to practice.

A new distance education facility in the College allows UW-Platteville to exchange course instruction with cooperating universities through an interactive compressed video system. This facility allows professors at other universities to teach students at UW-Platteville, and professors at UW-Platteville to teach students at other universities. In addition, the facility is available for outreach and extension programs and for guest lectures and professional meetings. The compressed video system enables interaction between participants in this facility and participants in compatible facilities elsewhere.

Articulation agreements provide opportunities for students to complete their first two years of study at one university before transferring to a cooperating university to complete course work for their engineering degrees. UW-Platteville has completed engineering articulation agreements with several other institutions in the UW System, including UWC-Baraboo/Sauk County, UW-Fox Valley, UW-Richland, UW-Parkside, UW-Stout, and UW-Whitewater (1).

The industrial engineering program at the University of Wisconsin – Platteville has been in existence since 1970, it was accredited by EAC/ABET in 1988. The Bachelor of Science in Industrial Engineering (BSIE) degree requires at least one of the four defined emphasis areas to be completed: Production Systems, Management Systems, Human Systems, and Information Systems. A total of 129 to 130 semester credits must be completed for the BSIE degree. The program has four full time tenure-track faculty members. Description of courses and other details of the program are at http://www.uwplatt.edu/ie/.

STUDENT ENGAGEMENT

Educational research on student engagement became popular in 1990s (2, 3). Initially it dealt with factors that enhance students' psychological investment in learning and factors that lead to their disengagement from learning activities. The Secretary's Commission on Achieving Necessary Skills (SCANS) report for America 2000 found that effective job performance required five competencies (effective use of resources, interpersonal skills, ability to acquire and apply information, understand complex interrelationships in systems and ability to use current tools of technology) and a three-part foundation of skills (basic skills, thinking skills, personal qualities) (4). The SCANS report provided a manual for teaching these competencies and skills.

The National Survey of Student Engagement (NSSE) in the Center for Postsecondary Research (CPR) at the Indiana University School of Education considers student engagement as two critical features of collegiate quality (5): the amount of time and effort students put into their studies and other educationally purposeful activities, and how the institution deploys its resources and organizes the curriculum and other learning opportunities to get students to participate in activities that decades of research studies show are linked to students' emotional commitment to learning (6).

Student engagement gained momentum when studies by Stanford Research Institute and the Carnegie Mellon Foundation among Fortune 500 CEOs found that 75% of long term job success depended on people, emotional or soft skills and only 25% on technical, discipline-specific or hard skills (7, 8). The Harvard University studies reported that achievements on career are determined 80% by soft skills and only 20% determined by hard skills. Technical skills are defined as "those skills acquired through training and education or learned on the job and are specific to each work setting," while soft skills are defined as "the cluster of personality traits, social graces, language skills, friendliness, and optimism that mark each one of us to varying degrees" (7,8). Student engagement activities consist of a wide variety of classroom and off campus work (5, 10) to develop both hard and soft skills required to have a successful career.

At UW-Platteville, the Pioneer Academic Center for Community Engagement (PACCE) was established in fall 2008 to nurture a campus environment to support student engagement through service learning, active learning and other community-based projects. It provides financial support to students under faculty direction to pay the costs of travel, supplies, services, and other associated community project expenses. PACCE is also a campfire where those involved with community-based engagement programs can meet to plan and coordinate awareness, advocacy, training, faculty development, assessment, and communications. Finally, it is a portal through which community and campus entities can meet, plan, and coordinate resources for the mutual benefit of each other. PACCE activities shown in Figure 1 allow students to engage with their course materials, take an active role in learning, reflect on their individual and collective experiences and develop while completing a team project for a community partner (9).

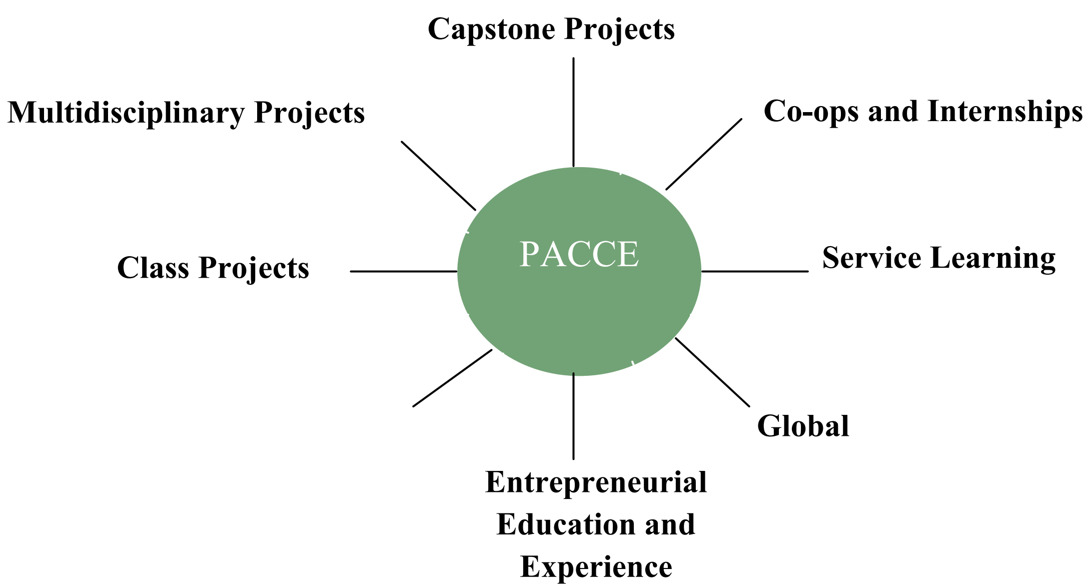

Figure 1: Student Engagement Activities

The PACCE Pioneer Engagement Scholars program provides up to $400 per student to offset the cost incurred by students in conducting a community-based scholarship of engagement project. Funds can either be disbursed to the faculty member for management on behalf of students in her or his class, or can be distributed to students directly for individual projects. Pioneer Engagement Scholars projects must be for credit, must include three committed partners (student, faculty/staff, community), and must include significant interaction between the students and community partner. Other critical components include student reflection of their engagement experience, dissemination of project results, resume quality professional recognition, and added-value for the community partner. The PACCE Engagement Internship program provides funding for student salary for those situations where an employer does not have the capability to pay the cost of an intern salary. Students must be pre-approved and be enrolled in a UWP internship program. PACCE's mission is that through Scholarship of Engagement, PACCE nurtures a campus environment that empowers students, faculty, staff, and community partners to Experience → Grow → Make a Difference as shown in Figure 2.

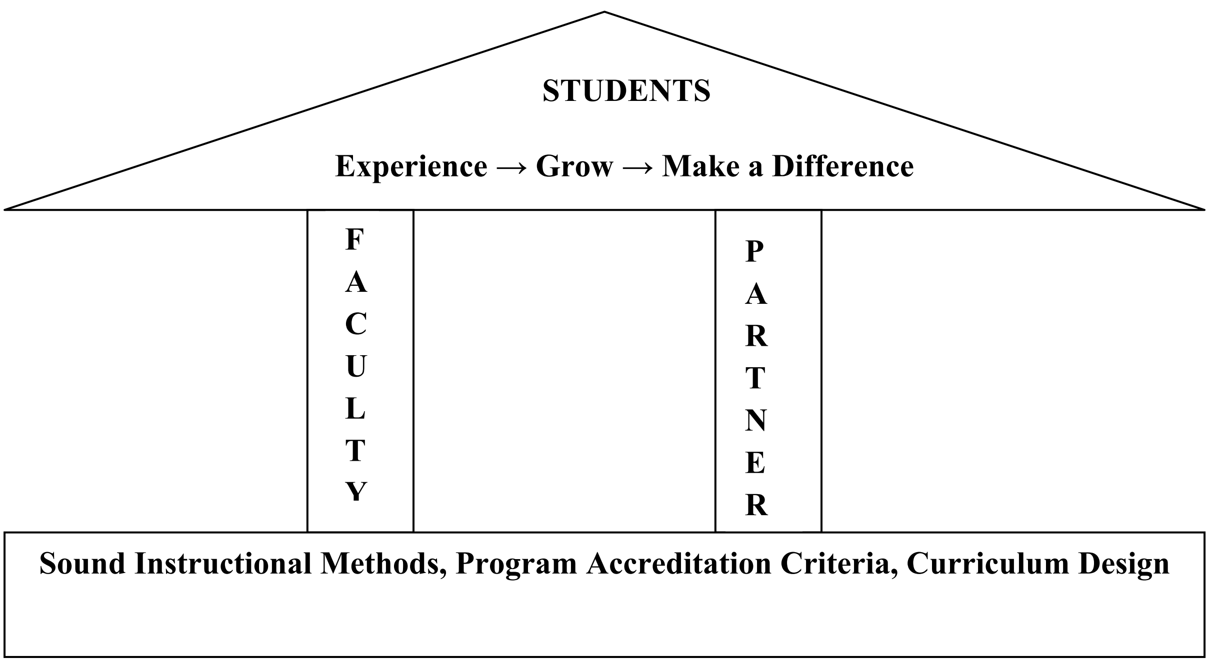

Figure 2: PACCE Mission

STUDENT ENGAGEMENT IN THE IE PROGRAM AT UW-PLATTEVILLE

In the mid 1980s, the primary rationale for using student engagement activities in the IE program was the accreditation of the program by the Engineering Accreditation Commission (EAC) of the Accreditation Board for Engineering and Technology (ABET). The criteria for accrediting engineering programs at that time required specified number of semester credit hours of instruction in engineering design. Engineering design was defined as the use of open-ended problems and case studies that included multiple constraints. The IE program utilized industry sponsored open-ended design projects or case studies from professional organizations in several courses in the curriculum to provide hand-on practical design experience to graduates. The senior-level capstone design course provided integrative experience in an industry sponsored project that allowed students to apply what they had learned in the lower level courses.

From 1970s through the 1990s the industrial design project sponsor reimbursed students' travel expenses. PACCE now provides support for such service learning projects in IE curriculum. This has allowed for more nonprofit organizations to become project sponsors. In fall 2008 with the approval of the Board of Regents, the university implemented the differential tuition plan which generated additional funds by charging $100 per student per year. This plan is scheduled to be reviewed after four years and it now supports a first-year experience program, counseling services, career services staff and PACCE. From fall 2008 through spring 2010 faculty members in industrial engineering received PACCE funds for about twenty projects in upper level courses. These projects were sponsored by community partners which are businesses, industries, social service organizations, libraries, university alumni services, etc. The service learning projects consisted of capstone design projects, multidisciplinary projects and class projects in upper level courses. Lists of past projects and brief description of each may be found at http://www.uwplatt.edu/pacce/past_projects.html.

REFLECTION

Student reflection, by individuals and team, is an essential component of PACCE grants. The PACCE grant proposal requires a description of reflection methods, questions, and techniques. The primary goal of reflection is to prompt students to think critically about the integrative design and team experiences before, during, and after the project. Individual and team reflections assist students in linking the course or curriculum to the project activities and assess the learning process and the outcomes. Through reflection students recognize the soft skills and hard skills they have acquired and refined in the service learning activities of the project. As success in their future career is likely to depend 80% on the soft skills and 20% on the hard skills, the reflection on these skills is important. Service learning projects develop a broad range of competencies classified as soft skills: oral and written communication, self-understanding, self-confidence, leadership, self-directed team skills, ethical and social responsibility, time management, coping with difficult people, etc. A few student reflections are presented below as examples.

Brittany Beinborn, Industrial Engineer: "I have gained more experience with working on real-life projects which will help me in my career. I have also been given the opportunity to apply numerous concepts I have learned throughout my four years of college to a situation I may encounter in my future work experiences. Also working in a team with four individuals has taught me a lot about teamwork skills, prioritization, and organization. My experience with the PACCE project has been very valuable and will help me greatly in the future."

Luis Peralta-Cervantes, Mexico: "Work with Nu-Pak Incorporated through PACCE was an excellent learning-process for me. I am a foreign-exchange student and I came here to learn the way the Industrial Engineers communicate each other, the concepts they use and the actions they use in a company to make improvements. After the project, I learned a lot about IE concepts, teamwork, how a real company works, how to give presentations, and mostly, how the American culture works."

A typical PACCE funded project was the emergency planning developed by three University of Wisconsin-Platteville senior design students, Jenna Walsh, Justin Goodrich and Antonio Encinas, for the Wisconsin Badger Camp. This camp, in Prairie du Chien, serves people

with developmental disabilities by providing quality outdoor recreational experiences. It strives to provide a positive environment where individuals with developmental disabilities can learn their surroundings and realize their full potential. The PACCE funds are being used for the group's travel expenses and to purchase emergency equipment such as fire extinguishers, stretchers and resource material. The group created training modules for staff, updated materials already in place and created an updated checklist of what to do in case of an emergency.
As part of the project, the group had to research federal and state safety regulations and understand project management. "Planning is an essential part of project management," said Goodrich. "We definitely used what we learned in class. The project made us more aware of regulation design and the consequences if regulation isn't followed."

SUMMARY AND CONCLUSIONS

This paper provided an introduction to the industrial engineering (IE) program at UWP and the Pioneer Academic Center for Community Engagement (PACCE). The paper summarized how student engagement has become larger in scope and now comprises of enhancing learning through service learning activities. The establishment of PACCE at UW-Platteville may motivate other universities to establish service learning programs. The paper presented a summary of PACCE service learning projects and student reflections in industrial engineering. These may be useful for faculty at other institutions.

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The Use of Extra Credit to Improve Course Design

Thomas Shepard
University of Minnesota

Abstract: This paper discusses the use of extra credit assignments in a semester-long introductory fluid mechanics course. During two semesters students (n = 180) had a chance to improve their grade by applying material learned in class to homework-type problems on topics for which time did not allow in-depth coverage. The problems were designed to expose students to the potential use of course material to real world applications while also incorporating critical math skills, yet these problems were much more challenging than an average homework problem. Half of the students took advantage of the extra credit increasing their grades by an average of 1.51%. Of the students who attempted the extra credit, 44% increased their letter grade for the course. The results show little difference in grade distribution between the students who chose to attempt the extra credit problems and those who did not, revealing that all types of students potentially can benefit from such assignments. This paper further discusses some of the more subtle benefits provided and how the manner in which extra credit opportunities are provided may improve course design.

Introduction

The topic of including extra credit in a course may invoke vigorous debate, with valid points on either side. Those opposed to offering extra credit cite arguments such as grade inflation, excess time planning and grading for the instructor, perceived fairness in when or to whom it is offered, lowering of academic standards, and a belief that during a semester a student has ample opportunity to achieve the grade they truly deserve. A further contention is that extra credit assignments can induce a moral hazard (Wilson, 2002). In this situation the fear is that by offering students extra credit they perceive less risk in performing poorly and will not study as thoroughly, as they will have the option to make points up in the future. The proponents of extra credit tout its ability to give students a second chance, rectify an exam which may have been too difficult, or explore topics in further detail than scheduled time may allow.

One gets the sense that many of the arguments against the use of extra credit pertain to the specific method in which it was provided. If this is true, judging all extra credit negatively would be akin to concluding that all the "Star Wars" movies are poorly done after only seeing "Star Wars: Episode I – The Phantom Menace". The manner in which extra credit is given is certainly tied to its merit as a tool in higher education. When used appropriately extra credit can be a versatile tool whether the goal is to introduce students to situations they will encounter in the workplace (Reid & Gwinn, 1997), increase lecture attendance (Wilder, Flood & Stromses, 2001), or make a connection between students and course material (Bicouvaris, 2000), just to name a few uses.

In this paper the use of extra credit assignments in a mechanical engineering fluid mechanics course is examined.

Project Description

The motivation for implementing extra credit assignments in this particular case arose from the desire to pace the class according to student learning. Specifically, the topic of solutions to the Navier-Stokes equation caused the students significant difficulty, resulting in a couple extra lectures reviewing calculus as it pertained to exact solutions. Due to this set-back, there was less class time to devote to pipe flows and drag, topics which are central to this subject and allow students to use many of the analytical skills developed throughout the course. This happened both in the fall and spring semester and the primary goal behind giving the optional extra credit problems was to allow students to see how the material they had been learning can be applied to real-world application problems. The extra credit was not listed on the syllabus but was announced to the entire class in the last few weeks of the semester and students were not required to complete all of the problems, but could receive credit for any partially solved problems. The potential maximum increase to a student's grade was 3.5%.

The problems were relatively challenging, required multiple steps, and forced students to use material learned in past courses (Statics and Dynamics, Thermodynamics), as well as relatively involved math. To make the problems seem less intimidating they were broken down into steps. Whereas a typical textbook homework problem is contrived to allow students to get practice doing a simple engineering analysis and help them learn the material, these problems were designed to allow students to see just how powerful all the tools we've given them are when combined. Even if time had allowed, presenting problems of this difficulty in class would be challenging. Because of the length of the problem many students' attention would wander and because of the difficulty some students may struggle to follow along even if their attentions were focused. All problems used can be found in the Appendix and it is noteworthy to mention that the extra credit assignment consisted of a single pipe flow problem and a single drag/lift problem each semester. The problems given to the second semester were on the same subjects but were new problems.

Results

Over both semesters a total of 180 students had the opportunity to do the extra credit problems and 50% of them took advantage. Interestingly, there was no significant difference grade-wise between the population of students who did the extra credit and the population that did not as demonstrated in Table 1. This result is opposed to the trend found in the literature which suggests that extra credit is predominately taken advantage of by the more gifted students in a class (Hardy, 2002; Moore, 2005). These cited works dealt with students in introductory biology and psychology courses making it possible that the difference is due to field of study, year in school, or whether the students were majors in the field or not.

	Average Grade (%)	Grade Standard Deviation (%)
Did Extra Credit	84	7
Did Not Do Extra Credit	83	9

Table 1. Grade performance of student populations

The students who did extra credit problems on average increased their grade 1.51%. This would amount to a cumulative grade increase of 0.76% for the classes suggesting minimal grade inflation. The class was graded on the plus/minus system (A, A-, B+, B, B-, ….) and 44.4% of the students who did the extra credit saw a single step increase (i.e. B to B+) in their letter grade suggesting that this option was attractive to students near a grade transition. The course was not graded on a curve and students could calculate their current grade at any point during the class which would have allowed them to know if they were borderline grade-wise. In general the students who were performing better in the class also performed better on the extra credit as shown in Figure 1.

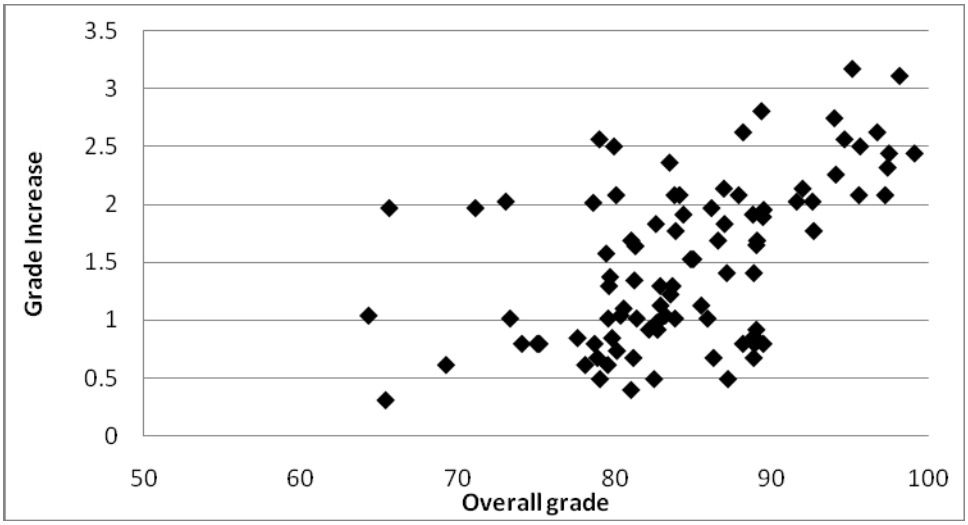

Figure 1. Distribution of extra credit performance vs. overall performance

Discussion

The administration of these extra credit assignments was well received by the students with a surprisingly large number taking advantage. The entire spectrum of abilities (D students to A students) participated and got to work with realistic problems that integrated skills learned throughout their engineering education, not just one chapter. The commonly stated downsides of extra credit were largely avoided with the main disadvantage relating to the time required by the instructor to create and grade the assignments.

Even the issue of raising a moral hazard was avoided by announcing the extra credit late in the class. If the same class were repeatedly taught by the same instructor it is anticipated that even if extra credit weren't listed on the syllabus word would spread and students would expect the extra credit to come at the end. This may create an apparent catch-22 where-in students possibly expect an extra credit assignment to be available to help them bolster their grade, and hence not give their full effort up front, whether extra credit will be offered or not. There may be some ways to mitigate this. First, have the total weight of the extra credit minimal; 5% of the total grade or less has been recommended (Palladino, Hill, & Norcross, 1999). Secondly, distribute the extra credit problems throughout the class, as opposed to having them all at the end. By diminishing the amount of extra points possible as the term progresses one might also diminish the moral hazard faced by the students while retaining most of the advantages of the extra credit problems. The challenge with this point would be in coming up with appropriately realistic problems early in the course, though one could have the students revisit material from a prerequisite course as it pertains to the pertinent subject. Finally, be up front with the students about the reasons behind the extra credit and how they will need to be quite comfortable with the material to do well on it. If they understand that the extra credit is not intended as an opportunity to make up missed points, but is aimed at exploring the applications of skills learned they may be less inclined to use it for the former.

Providing students these extra credit assignments also provided some subtle benefits from an instructor's standpoint. By getting feedback from the class and pacing it accordingly, as well as offering extra credit, the class appreciated that the instructor had compassion and was willing to consider their input. This was reflected in comments in the teaching evaluations at the end of each semester. It also minimized concerns over the class not being curved by allowing students to bolster, or insure their grade prior to the final exam. Additionally, by allowing for improved student grades one may expect improved evaluations in general as well as improved retention in a given field of study. It is important to reiterate that these grade improvements did not come at the expense of grade inflation, which may produce a similar effect but at the cost of lowering standards. Finally, developing original problems is useful if you want to contribute to a textbook. Two of these problems served as a starting point for end of chapter home work problems accepted for *Introduction to Fluid Mechanics 8th Edition* by Fox, Pritchard and McDonald.

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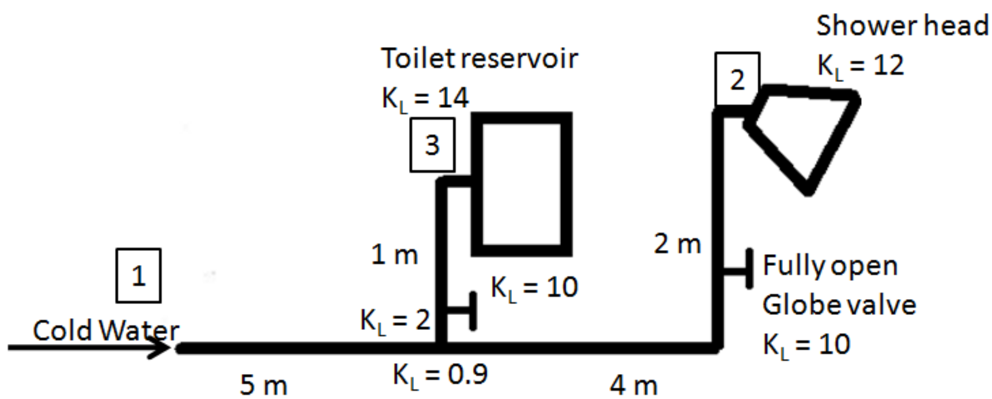
Appendix

Extra Credit Problem 1

Examine the effect of flushing the toilet on the temperature of the shower.
The temperature of the shower water is 44˚C, the cold water supply is 12˚C and the hot water heater is set to 65˚C. The plumbing of the bathroom consists of 1.5 cm diameter copper pipes with multiple connections; the cold water supply is shown below. If the gage pressure at the inlet of the system is 200 kPA during a shower and the toilet reservoir is full (no flow in that branch), determine the temperature of the shower when the toilet is flushed.

Assume that the hot water flow rate is not affected by the flushing of the toilet; assume a uniform internal energy of the water across the shower head. Use the loss coefficient of threaded connectors for the elbows (K_L=0.9).



Solution procedure:

1.Find Qcold (use the energy equation and Colebrook equation)

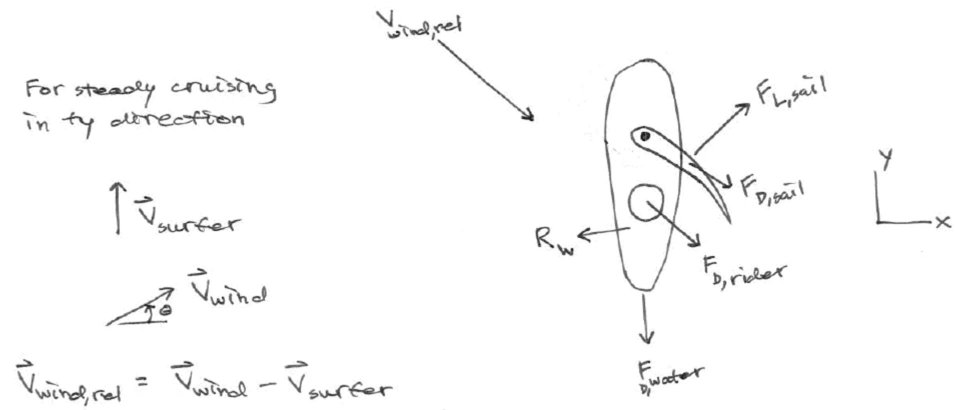
2. Knowing Qcold, do an energy balance on a CV with Qcold and Qhot entering and Qshower exiting (neglect changes in PE and KE). The continuity equation will also be needed, and maybe a Thermo text to determine internal energies or enthalpies. The goal in this part is to determine Qhot.

3. Find Qcold at the shower head when the toilet is flushed. You'll use the energy equation from 1 to 2, and from 1 to 3, the continuity equation and 3 Colebrook equations. This gives 6 equations with 6 unknowns (V1, V2, V3, f1, f2, f3).

4. Once the new Qcold is known another energy balance using the Qhot determined previously can be used to determine the new shower temperature.

Extra Credit Problem 2

The windsurfing speed record was set in saltwater on a day when the wind was blowing at 50 knots and the sailor was using a sail with an area of 4.8 m^2. The sail is like a vertical airfoil which produces lift and drag as the wind blows across it. There will also be a drag force on the sailor as well as drag due to the interaction of the board with the water. The fin of the board produces a force (R_w) in the horizontal direction so that the windsurfer is not simply blown downwind. The forward motion of the windsurfer creates an apparent wind ($V_{wind,rel}$)that is a combination of the true wind and the wind created by this forward motion. The angle of attack of the sail will be in reference to this $V_{wind,rel}$ and it is incorporating the different angles which proves challenging in this problem.



The goal is to determine how fast the windsurfer will go for a certain set of conditions. Those conditions are: V_{wind} = 50 knots, A_{sail} = 4.8 m^2, Sail aspect ratio (AR) = 3, wetted board area = 0.25 m^2, angle of V_{wind} = -15°, angle of attack of sail (α) = 2°.

Solution Procedure:

1. Conduct a force balance in the y direction.

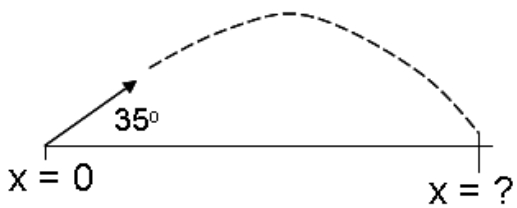
2. To determine the lift and drag on the sail assume that Figure 9.33 holds true for the sail.

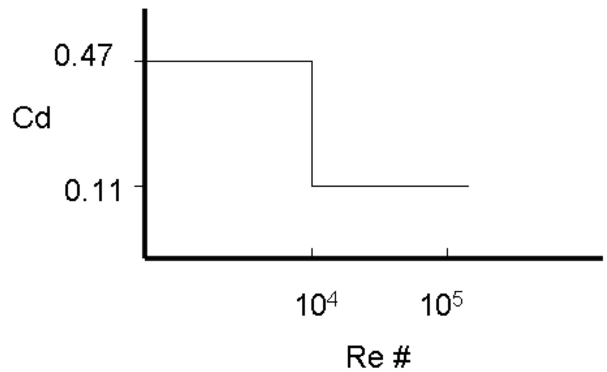
3. Determine the drag on the board. The board can be treated like a flat plate with a turbulent boundary (section 9.2.5). From this, and noting that the length scale to use in the Reynolds number for this case is the square root of the wetted board area, the drag due to friction on the board can be determined. To account for any pressure drag and wave drag incurred simply multiply the friction drag by 2.35.

*Note that Figure 9.33 and section 9.2.5 are referring to *Introduction of Fluid Mechanics, 5th Edition* by Munson, Young and Okiishi.

Extra Credit Problem 3

A baseball leaves Justin Morneau's bat at 110 mph with an angle of 35^o. Estimate how far the ball will travel before it lands. Baseball diameter = 2 7/8", Baseball mass = 0.143 kg, consider air at standard properties, and baseball drag coefficient as shown below.





a) What is the initial Reynolds number?

b) At what speed will Cd increase from 0.1 to 0.47? Do you think the ball will land before slowing down to this speed?

c) How long will the ball be in the air? Consider just the vertical component of velocity. Assuming that Cd is constant (can this be justified by part b?) determine how long it will take the ball to reach the top of its trajectory (going from V initial to V = 0). It may also be helpful to determine the height reached. Next determine how long it will take to fall from its maximum height. (assuming it lands with the same velocity it started with in the vertical direction would be incorrect).

d) Now that you know how long the ball is in the air you can determine how far it travels in the horizontal direction during this time. Consider just the horizontal component of velocity and again assume that Cd is constant (is this still justifiable?) It may be helpful to determine the magnitude of the horizontal velocity that the ball will have when it lands so that this can be used as a limit of integration. (i.e. there may be an integral from x1 to x2 and an integral from U1 to U2 involved)

e) How far would the ball travel in Denver?

Extra Credit Problem 4

Realizing that your mortgage payments would not be much higher than your current rent you recently rushed into buying a foreclosed house. Unfortunately your house is 100 years old and the water pressure is terrible on the 2^{nd} floor of the house. Below is a rough schematic of the plumbing system. After talking with some people and digging around a little bit you have determined that there are a few reasons why your water pressure is so low.

1. You house is in an old part of town with an old crudded up water main making the available pressure to your house lower than it should be.

2. Your home should really have a ¾ in. pipe coming in from the water main whereas it currently has a ½ in. pipe.

3. The pipes in your house are old and extremely crudded up by deposits over the years. This creates a large effective surface roughness and decreases the effective pipe diameter from what it should be.

Pretty much what you have on your hands is the perfect storm of plumbing issues. It may be helpful to think of the piping system as 3 sets of pipes: P1 is the piping from the water main to the house, P2a is the cold water piping that runs from the 1^{st} shut off valve (gate valve) to the branching tee that goes to the hot water heater, P2b is the cold water line that runs from this tee up to the shower head, and P3 is the piping that carries hot water.

$P_{water\_main} = 45$ psi	$D_{2a} = D_{2b} = D_3 = 0.0095$ m	let $\alpha \approx 1$
$D_{water\_main} = 0.128$ m	$\varepsilon_2 = 0.003$ m	
$\varepsilon_{water\_main} = 0.003$ m	$\varepsilon_3 = 0.006$ m	

For this problem neglect minor losses due to unions, the water meter, the hot water heater, and simply consider the first gate valve which has a contraction and elbow inside of it to be a regular gate valve. The loss coefficient for the shower head is $K_L = 12$ and the shower head can be considered to have the same diameter as D_2 or D_3.

Questions:

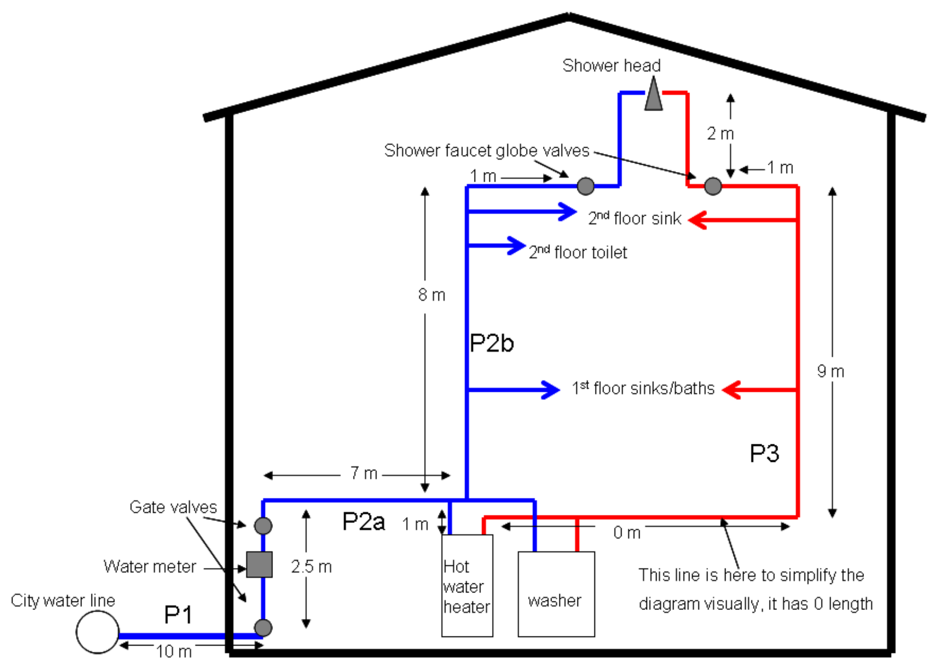
a) What will be the volume flowrate from the shower (in gallons/minute) if you turned the cold water on fully and kept the hot water turned off? Are minor losses significant? Is the velocity head significant?

b) What will be the volume flowrate from the shower (in gallons/minute) if you turned the hot water on fully and kept the cold water turned off? Are minor losses significant? Is the velocity head significant?

c) Two possible solutions to your problem that people are trying to sell you on are: 1. replacing the pipe from the water main to the house with smooth pipe with a diameter of ¾ in, 2. replacing the piping inside the house (P_{2a}, P_{2b}, P_3) with smooth piping with a diameter of ½ in. Calculate how these solutions would affect the flowrate of hot water when the cold water is shut off.

d) A final possibility would be to install a booster pump just before the branch tee to the water heater while not replacing any of the current piping. If you wanted to get a flowrate of 2.5 gallons/minute of just hot water, what pressure would the pump have to boost the system to? What would the pressure on the upstream side of the pump be? (The pump will have a low pressure on its upstream side so that the pressure drop between the water main and the pump creates the desired flowrate and it will have a high pressure on the downstream side so that the pressure drop between the pump and shower head matches this flowrate.) Is the pump idea physically possible for the desired flowrate and current pipes? What is the best flowrate you could achieve with a booster pump?

e) If replacing the pipe to the house costs \$3500 while the cost to re-pipe the house (and fix all the holes in the walls created) is \$6000 and a booster system costs \$1000 which would you choose to fix the problem? Why?



List all assumptions used and justifications for their use.

Impact of Student Involvement in a Solar Wall Study for the State of Minnesota

Joseph Dobmeier, Joseph Gehrke, Matthew Simones, Patrick Tebbe
Mechanical & Civil Engineering Department
Minnesota State University, Mankato

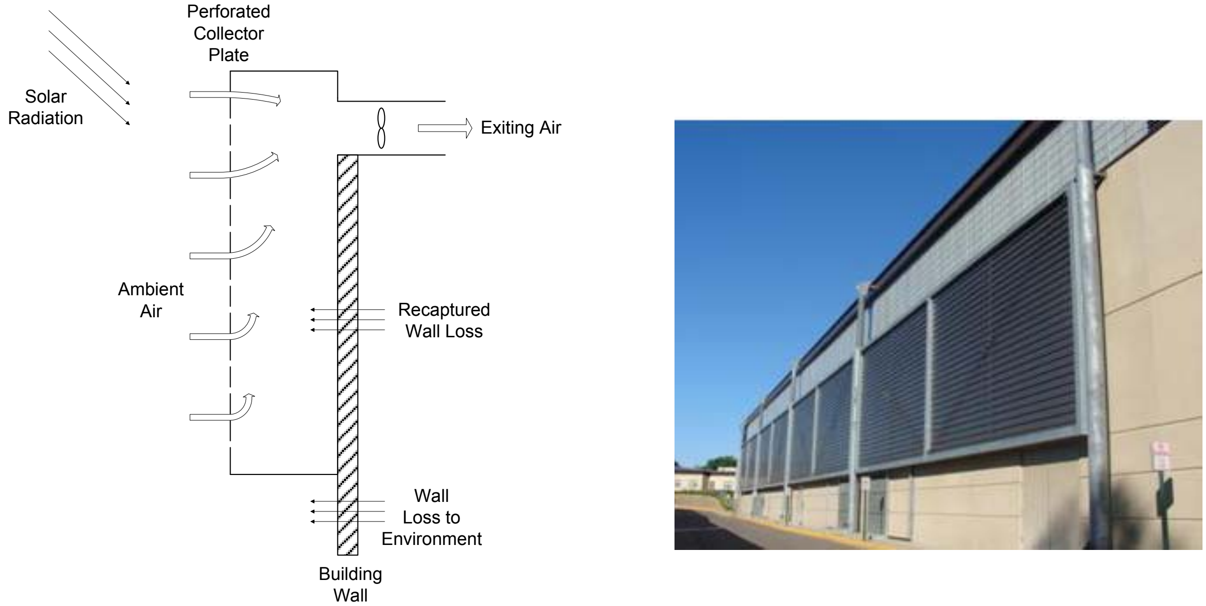
I. INTRODUCTION

In 2008 Minnesota State University, Mankato (MSU) received a grant from the Minnesota Department of Commerce to study the reduction in carbon dioxide emissions achieved through the use of unglazed transpired solar collectors (UTCs), as requested by the Minnesota Department of Energy Security. From beginning to end, student contributions were vital to the success of the project. The UTC project was beneficial for the students involved because it allowed them to gain a much broader understanding of technological ventures than they would acquire from a typical lecture based approach alone. The deliverables for the project were performance characterizations of UTCs for multiple sites based on measurements of air temperatures and solar irradiance combined with component specifications for the buildings under study. This required extensive communication between the students and a number of industry actors including architects, HVAC engineers, equipment suppliers, construction contractors, and building operators. In addition, the students performed a literature review and interacted with faculty in order to develop a mathematical model representative of the UTC and its associated HVAC system. The model was designed to incorporate data and specifications collected from original design drawings, actual construction methods, equipment technical sheets, building management systems, and experimental instrumentation. Setup of the experimental rigs was a major undertaking in itself since temperature probes and data logging equipment had to be attached to the buildings under rather inauspicious conditions.

In this paper the UTC concept and research results will be briefly reviewed. Next, the contributions of students will be outlined along with assessments of the project's impact on students' comprehension of the role of research in the industrial enterprise. Finally, specific examples will be elaborated and conclusions drawn about the suitability of such projects to complement traditional lecture-based instruction.

II. PROJECT BACKGROUND

The UTC, as depicted in Figure 1, is a solar energy conversion technology which relies upon a dark colored perforated plate to absorb energy from the sun which is then transferred to incoming ventilation air. Doing so reduces the amount of fossil fuel consumption necessary to raise the ventilation air temperature to the building's supply air requirement. A study of the system involves many competing and complementary forces which do not lend themselves to a simplified solution. The intent of the MSU project was to determine experimentally how these systems perform in a Minnesota climate. The results have shown that UTCs are capable and appropriate for use in the Minnesota climate, with one site giving a heating season energy savings total of approximately 74 MBtu per square foot of collector area. The analysis also



(a) (b)

Figure 1: Examples of unglazed transpired solar collectors, (a) schematic and (b) installation at Breck School gymnasium.

detailed the separate contributions of active solar gain, recaptured building wall losses, and reduced building wall losses to the total energy savings.

Throughout the project there has been a strong focus and reliance on the assistance of student researchers. Several of these students have worked on the project for multiple semesters, taking on new tasks as their experience has grown. The research group throughout has been multi-disciplinary with Physics and Mechanical Engineering faculty and students. Undergraduate and graduate level students have also worked together. It was quickly found that scheduling issues for the repeated on-site visits would make it difficult for faculty to personally oversee all activities. Therefore, a process of peer mentoring was relied on with more experienced students leading the development of new students on the project. As students rotated off the project (due to graduation or other responsibilities) efforts were made to ensure that new students were fully trained by the time they would need to take over tasks.

III. PROJECT TASK BREAKDOWN

The first task performed for this project was a literature review. Students extensively searched journal articles from the campus library and online databases. While this is a required component for any graduate thesis, it was a novel experience for the undergraduates involved. The selected articles were archived by the students on a website under the campus domain to facilitate information sharing among team members. A review paper was then written which summarized the material and was included on the same website. This involved reviewing a number of published graduate theses, identifying assumptions, and discussing these with faculty.

I started on the UTC project during the summer after my junior year as a mechanical engineering student. At the time I was anxious to apply my knowledge of thermo/fluid sciences and mechanical design toward a real world application/engineering project, as well as learn more about renewable energy. The UTC project provided that experience allowing me to gain knowledge in passive solar energy systems and experience in conducting experimental research. Overall I feel fortunate to have the opportunity to be part of this project. I have learned more than I imagined at the beginning of the project and I have already applied some of these skills toward my graduate research.

-Student Researcher

Next, an experimental plan was developed to obtain the required data. The primary component was off-the-shelf weather stations with sensors for air temperature and humidity, wind speed and direction, and solar irradiance. To facilitate data collection and storage the weather stations were equipped with wireless data transmitters. A key parameter was the air temperature exiting the collector. Since the majority of sites were not equipped to measure this the weather station was outfitted with extra temperature sensors for insertion in the ductwork exiting the UTC.

Visits to the sites then had to be coordinated for equipment setup. Weather stations were installed at three sites; two of which had extra temperature sensors placed in the UTC air duct to monitor outlet temperatures. This required additional planning and work to install the sensors in the proper positions along with the use of unfamiliar tools to complete the installation (i.e., a telescoping boom and scissor type aerial lift platform used to route wiring and install sensors). An important aspect of this was proper safety training and the use of safety equipment.

One of the sites also incorporated a temperature profile measurement system consisting of eighteen thermocouples along with a separate data logger. This system measures the surface and interior temperatures of the wall. The thermocouples were installed in two 3x3 arrays, one on the surface of the collector and one close to the building wall. They were then connected to the data logger where temperature data was stored. Each sensor was mounted in a custom made mount designed to be inserted where existing connectors already existed (to minimize additional damage to the wall).

Two other students and I had to install eighteen thermocouples and wiring on the UTC at Breck school. Basic hand tools and a lift was all that was required to install the sensors, but it took us two trips over a period of a week to complete the installation because the weather was not cooperative on the days we worked. It was a combination of rain and snow the first day. The lift used to install the thermocouples somehow got moisture inside the control. This caused the hoist to stop working and it wasn't able to get repaired until the next day. Because of this we had to plan a second trip up to Breck to finish the installation. This day was also a combination of rain and snow which made the overall installation go a lot slower than planned. This goes to show that no matter how much planning goes into a project there can always be those unexpected things that can slow you down. This experience has shown me that the best you can do in these situations is accept that things didn't go as planned and just keep moving forward.

Student Researcher

Finally, each data logger was configured and initiated through the use of software available from the manufacturer. The software was downloaded to a laptop which then functioned as an interface to the data logger hardware. The design and installation complemented the conventional instruction the students received in Experimentation and Machine Elements classes and provided unique challenges which are difficult to duplicate in a classroom setting.

Once the equipment was installed, data collection from the sites could begin. Data from the weather station sensors was easily collected because it was all transmitted wirelessly to a web server. From there the data could be conveniently downloaded for analysis. Data collection for the thermocouple array was much more complicated. Since the data logger for the array didn't come with wireless capabilities, it necessitated manual, on site, downloads to a laptop. Also, the capacity of the logger's battery pack (which consisted of twelve size D batteries) limited the collection interval to a maximum of two weeks. This required trips to be made every other week or sooner to collect the data and install new batteries. In spite of this drawback, the data logger worked well and provided the students an excellent experience with collecting data in the field. It also provided a good opportunity for students to practice time management and communication skills (the students needed permission to access the data logger because it was on the roof of the Breck School's gymnasium).

> *Previously I had no experience working with specialized software for experimental data collection. On top of that, I never had any experience with this type of data logging system (standalone systems). Working on this project gave me invaluable experience with downloading data from a data logger and using software that can program and communicate with the data logger. It also made me conscious of the types of data logging systems that are available, for future reference.*
>
> *Student Researcher*

To facilitate data analysis, building and equipment specifications were gathered for all the sites. To achieve this, the students' first point of contact was the building operators. They provided information about the architects, design engineers, and construction contractors involved. Unfortunately, contacting these people proved to be one of the biggest challenges of the project. Issues such as personnel no longer being employed with their respective firms or being too busy with other projects to help seemed to be the norm. Were it not for the fortunate circumstance that multiple MSU alumni (who went out of their way to help) happened to be employed with the firms, the project could easily have been stalled. Building operators were also able to provide many original design documents and specifications when other avenues were exhausted. Needless to say, the students gained valuable experience from both successful and unsuccessful communication attempts. The importance of professional networking was made strikingly obvious. Furthermore, the influence of economic factors became apparent while requesting information. In some cases, industry partners initially appeared cooperative but were simply too overworked to provide much assistance. From the students' perspective, this was the least engaging aspect of the project.

In addition to specifications, building operators assisted with data collection from their own energy management systems. Students worked closely with them to determine what their systems were capable of measuring, how to best exchange data, and in what format the data would be provided. This phase of the project gave the students an intimate look at actual buildings and their environmental control systems. Concepts from courses such as Air Conditioning and Refrigeration, Automatic Controls, and Experimentation Labs were applied to understanding the practical implementations. While interacting with the operators, students were exposed to alternate viewpoints on the systems they have been learning to design.

> *Examining the physical processes at work in the system and relating them back to theoretical descriptions presented in class was a great opportunity to apply the knowledge I have attained. I found it interesting to see how concepts which are given separate treatment during instruction are very interrelated in practice. The lines were blurred between what I had hitherto considered separate problem domains, i.e., using psychrometric principles to define properties of moist air within an otherwise textbook heat transfer problem.*
>
> *Student Researcher*

Following data collection, an analysis was performed. The purpose of the analysis was to determine the amount of energy saved from drawing air through the collector plate, as opposed to ambient outside air. The relative contributions of each component were also determined: active solar gain, recaptured wall losses, and reduced wall losses. This was accomplished by defining a physical model of the system that was utilized, along with the collected data, to calculate the variables of interest. Defining the model drew upon knowledge gained in junior level courses such as Fluid Mechanics, Heat Transfer, and Thermodynamics as well as the electives: Air Conditioning and Refrigeration and Thermal/Fluid Systems Design. Extensive use was made of the spreadsheet program Microsoft Excel combined with programming written in Visual BASIC for Applications. During coursework, particularly laboratory sections, simple charts and calculations are made with Excel but the scope and complexity of this project went far beyond what is typically expected in an undergraduate course. Overall, the individual tasks performed in this phase of the project deviated from traditional classroom instruction the least; yet it was also the most holistic, in terms of technical content, of all the phases.

One of the deliverables for this research project was a journal submission to ASHRAE (American Society of Heating, Refrigerating, and Air Conditioning Engineers). First, all the information on the project was pulled together and organized. Summaries for all the test sites were written which included background information, UTC characteristics and installation details, operation of the energy management system, and a review of the sensors used and their specifications. The analyzed data was presented in plots and tables and an overview of the results was written to explain the data and the modes in which UTCs reduce energy usage. This information was then compiled into a draft paper that was reviewed and edited several times before it was submitted to ASHRAE. The paper will be peer reviewed and published as an ASHRAE conference journal article (that includes the names of all the students involved in the project) which can be accessed by engineers worldwide. This gives the students a concrete way to show the work that they completed on the project. Besides getting their names on a paper that will be published by a national organization, this portion of the project helped the students strengthen their skills in time management, proof reading and editing papers, and meeting deadlines.

Working on ASHRAE paper has benefited me in several ways. Learning about the attention to detail required to write for a professional journal was truly eye opening. A large amount of time was spent on making sure the text was in the proper font and size, plots and tables were in the mandatory format, and just the right amount of information was included in the paper because there were restrictions on how long it could be.

Student Researcher

IV. SUMMARY

Most engineering programs employ student outcomes which include, or are modified from, the standard ABET a-k outcomes. The student impact of this research project can be judged by determining the outcomes that have been addressed. An examination of student activities reveals that all of these outcomes have been touched on by the research project.

Overall, this project was an invaluable experience to the students involved. The students were unanimous in the opinion that the project was able to tie together diverse elements of their education. It has helped to reinforce concepts and skills that were learned in the classroom. Using mathematical equations to analyze data; applying thermodynamic and heat transfer concepts to understand flow rates, temperature differences, and energy transfers; and incorporating soft skills such as spell checking, paper formatting, and use of proper grammar are all examples of learned classroom skills used on this project. More importantly it has given the students experiences that are impossible to duplicate in the classroom. Communicating with people in industry, coping with unexpected problems, and working with specialized tools are just a few examples. This research project has exposed students to a renewable energy source and the significant economic benefits of using energy wisely and efficiently. It also gave the students an idea of the importance that further development of renewable energy technologies has for society. With these newly gained experiences, the students involved will now be better prepared to face the many challenges that they will face in school, in their careers, and beyond.

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BIOGRAPHICAL INFORMATION

JOSEPH DOBMEIER is a graduate student in mechanical engineering at Minnesota State University, Mankato.
JOSEPH GEHRKE is a senior undergraduate in mechanical engineering at Minnesota State University, Mankato.
MATTHEW SIMONES is a graduate student in mechanical engineering at Minnesota State University, Mankato.
PATRICK TEBBE is an Associate Professor of mechanical engineering at Minnesota State University, Mankato.