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The Iron Range Engineering (IRE) Model for Project Based Learning in Engineering

Daniel Ewert, Ron Ulseth, Bart Johnson, Andrew McNally
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Abstract
In the heart Minnesota’s Mesabi iron range, a new model for engineering education has been funded and began delivery in January 2010. The IRE (Iron Range Engineering) model is a project-based-learning (PjBL) model in which students work with industry or entrepreneurs on design projects with a focus on producing graduates with integrated technical/professional knowledge and competencies. Students at IRE are upper-division mechanical engineering students, enrolled at Minnesota State University Mankato, who are mostly graduates of Minnesota's community colleges. IRE students do not take classes; 100% of their learning is done in the context of the industry/entrepreneurial projects. The PjBL model readily lends itself to regional economic development making the IRE program an education/economic hybrid system.

Overview
Since the publication of Engineer 2020 [1] (and before) there have been numerous calls for a new-look graduating engineer. With guidance from some of the most respected leaders in engineering education, the IRE model has been developed to utilize industry-based project-based-learning (PjBL), outcome-based assessment, just-in-time interventions, self-directed learning, and emphasis on reflection to graduate engineering practitioners with integrated technical/professional competency.

Educating Engineers: Designing for the Future of the Field [2] together with other recent research and reports on engineering education, make a compelling case for envisioning engineering education in a new way. The new Iron Range Engineering program explores a completely different way of approaching engineering education. Some of the characteristics of this new approach are:

* Primary emphasis is on development of learning outcomes that have been spelled out in national reports, including The Engineer of 2020. This emphasis is contrasted with primary emphasis on coverage of topical material that characterizes many of the engineering programs throughout the world.

* Faculty members in the program invest heavily in developing abilities of students in the program to assess their development with respect to these outcomes. To support self assessment, faculty members articulate criteria with which development with respect to these outcomes can be evaluated.
* Learning activities are organized around externally-sponsored projects. Each semester, students manage projects in which they perform engineering functions such as design, development, research, testing, etc. for local and regional industries and entrepreneurs. Faculty members use the projects as contexts for developing competencies and learning subject matter.

* This contextual problem based learning model provides an exciting environment for synergism between education and economic development. Learning by working on externally sponsored projects from industry and inventors, the innovation process is moved into the undergraduate education process and allows for more globally competitive regional industries and the promise of new hi-tech start-up companies.

* Students complete course and graduation requirements by exceeding or meeting levels of competencies with respect to clearly articulated outcomes using a modified Bloom’s Taxonomy.

**Rationale Supporting Need of “New Look” Engineer**

The evidence for needing and the calls for a new model of engineering education are extensive. These calls have come from a wide variety of sources, such as:

- **The National Academies of Engineering (NAE) in *The Engineer 2020* and *Educating the Engineer of 2020* publications:**
  
  "If the United States is to maintain its economic leadership and be able to sustain its share of high-technology jobs, it must prepare for this wave of change. Although there is no consensus at this stage, it is agreed that innovation is the key and engineering is essential to this task; but engineering will only contribute to success if it is able to continue to adapt to new trends and provide education to the next generation of students so as to arm them with the tools needed for the world as it will be, not as it is today." [3]

- **The National Science Board (NSB) in *Moving Forward to Improve Engineering Education*:**
  
  “The Board feels that a continuation of the status quo in engineering education in the U.S. is not sufficient in light of the pressing demands for change”. [4]

- **The leaders in engineering education through several American Society for Engineering Education (ASEE) Journal of Engineering Education (JEE) Articles:**
  
  "Converging on a view of engineering education that not only requires students to grasp traditional engineering fundamentals, such as mechanics, dynamics, mathematics, and technology, but to also develop the skills associated with learning to imbed this knowledge in real-world situations. This not only demands skills of creativity, teamwork, and design, but in global collaboration, communication, management, economics, and ethics." [5]
"In view of the broadening and rapidly shifting scope of the engineering profession, it is imperative to shift the focus of engineering curricula from transmission of content to development of skills that support engineering thinking and professional judgment. Future engineers will need to adapt to rapidly changing work environments and technology, direct their own learning, broaden an understanding of impact, work across different perspectives, and continually revisit what it means to be an engineer. Traditional approaches to engineering education (chalk-and-talk lectures, individual homework, three years of “fundamentals” before an introduction to engineering practice) is incompatible with what we know from decades of cognitive and classroom research”. [6]

The need for change is not new and should be considered part of the continuum of change our society is going through. The same need existed in the middle of the 20th century in the United States as summarized in:

- President Barack Obama's Remarks at the April 27th, 2009 National Academy of Science Annual Meeting:

  "A half century ago, this nation made a commitment to lead the world in scientific and technological innovation; to invest in education, in research, in engineering; to set a goal of reaching space and engaging every citizen in that historic mission. That was the high water mark of America's investment in research and development. And since then our investments have steadily declined as a share of our national income. As a result, other countries are now beginning to pull ahead in the pursuit of this generation's great discoveries ... That's why my administration has set a goal that will greatly enhance our ability to compete for the high-wage, high-tech jobs of the future -- and to foster the next generation of scientists and engineers. In the next decade -- by 2020 -- America will once again have the highest proportion of college graduates in the world. That is a goal that we are going to set." [7]

It is in the context of a defined need for change, the call for change, and the *Educating the Engineer of 2020*'s call for system level approach that the IRE model was developed.

**Rationale Supporting IRE Model**
The same sources that have called for a change in engineering education have also given directions for this change that led to the aspects of the IRE model of student empowered development of technical and professional knowledge and competencies in context of industry sponsored project-based learning.

The call for engineering education to be **student empowered** (or centered) **development of competencies** is summarized in the:

- *Educating the Engineer of 2020* focus on the need for student focus in the curriculum development:
  
  *"Pursue Student-Centered Education - One should address how students learn as well as what they learn in order to ensure that student learning outcomes focus on the performance..."*
characteristics needed in future engineers. Two major tasks define this focus: (1) better alignment of engineering curricula and the nature of academic experiences with the challenges and opportunities graduates will face in the workplace and (2) better alignment of faculty skill sets with those needed to deliver the desired curriculum in light of the different learning styles of students." [1]

The focus on **technical competencies** has been a hallmark of engineering education, but the need for **professional competencies** to be addressed as an equal are more than evident in the:

- *Educating the Engineer of 2020's* recognition that "the disconnect between the system of engineering education and the practice of engineering appears to be accelerating. This is due to the explosion of knowledge, the growing complexity and interdependence of societal problems, the worldwide reach of those problems, and the need to operate in a global economy” [3]

- **ABET Criterion 3, program outcomes;** where out of the 11 outcomes that programs must demonstrate their students attain, the following 7 have a professional component to them [8]:
  - (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
  - (d) an ability to function on multidisciplinary team
  - (f) an understanding of professional and ethical responsibility
  - (g) an ability to communicate effectively
  - (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
  - (i) a recognition of the need for, and an ability to engage in life-long learning
  - (j) a knowledge of contemporary issues.

The IRE model is designed to specifically meet the model of engineering education being called for by those leading the way for engineering education to meet the engineering needs of the future.

**Description of Revolutionary Model for Engineering Education in the United States**
The IRE model was delivered for the first time starting in January 2010 in Virginia, Minnesota as a collaboration between Itasca Community College and Minnesota State University Mankato.

The IRE Model is:

| Student empowered development of technical and professional knowledge and competencies in context of industry/entrepreneur sponsored project-based learning, leading to regional economic development |

**Project-based-learning (PjBL):**
In an adaptation of the Aalborg Model of PjBL (Figure 1), IRE students combine learning of technical information with the execution of engineering design projects (note: this model is 100% project based and does not include traditional courses).
Entering students are community college graduates or transfer students from other universities who have all completed lower division requirements for a BS in Mechanical Engineering. The IRE model is the four semester upper division portion of a student's education. Graduates will be conferred a bachelors degree in mechanical engineering. Students execute one to two project cycles per semester.

During the proposal stage, students, in collaboration with faculty and clients, develop two plans: a design "work plan" which details the entire execution of the deliverable to the client; and a "learning plan" which addresses professional learning objectives, technical learning objectives, and the learning modes that will be employed to meet the objectives (self-directed learning, peer-directed learning, faculty-directed learning, and external expert-directed learning as well as methods for formative assessment and reflection).

Figure 1. An adaptation of the Aalborg Model of PjBL for use in the Iron Range Engineering Program [9]

Projects are industry or entrepreneur sponsored. IRE is located in the heart of Minnesota's Iron Range. Within short driving distance there are five iron mines, two coal generation power plants, a wind-turbine farm, two paper mills, a new precious metals mine, and proposed steel mill. The managers and engineers in these industries have embraced this program and committed to providing projects, project guidance, technical expertise for student learning, and assistance in assessment. As an example of a project – In Spring 2010, an IRE student group designed and implemented a condenser performance test to be applied to the power generation condenser on a 400 MW power plant. The performance test will give several indications of efficiency both before and after the condenser is retrofitted. The results of the testing will give Minnesota Power vital information on the cost savings and payback period. To perform the project, the student group learned cycle analysis, conduction heat transfer, convection heat transfer, heat exchanger
design, engineering economics, evaluation theory, and studied the environmental implications all in the context of a real deliverable for a major client. A technical report was published and five oral presentations were made.

As another example of the PjBL model effectiveness, four design projects were entered into a statewide business plan competition with over 1000 total entries. The IRE program placed 3 of the four in the top 10 in their respective divisions, with one placing in the top 3 as a finalist.

**Technical and Professional Knowledge and Competencies:**
The IRE developers have broken technical and professional knowledge and competencies down into a finite number of measurable outcomes. For each outcome, a continuum from novice to expert using Bloom’s 2D taxonomy (see Figure 2.) is being applied.

In the beginning of each student's first semester, she works with faculty to establish her individual starting point on each outcome. In this way, the IRE model recognizes each student's different starting points and empowers all students to build on their strengths and overcome their weaknesses as they navigate their education. To graduate, each student has to attain "work ready" competency.

**Student empowered design and monitoring**
A guiding principle for the IRE model is that students own the responsibility for their learning. At the beginning of each project cycle, students identify which outcomes will be addressed during the project. Working with faculty, they determine which learning modes will be applied and determine what types of evidence they will need to acquire to demonstrate outcome attainment by the end of the project cycle. Each project cycle concludes with the presentation of two reports - a design report for the deliverable and a learning report that reflects on the learning process and provides evidence of outcome attainment. In addition to written reports, there is a student presentation made to faculty and external clients. The final presentation includes an extensive oral exam session in which students demonstrate their understanding of technical engineering knowledge gained and competencies acquired. At the conclusion of each project cycle, students have a new view of their levels of knowledge and competencies.

**Brief History**
In March 2009, the Minnesota Iron Range Resources Board (a group of eight members of the Minnesota State Legislature) decided to establish a new engineering program on the Iron Range in Minnesota. The program is the result of five years of planning and development by a small team of engineering educators from across the country. This group sought to use the new knowledge on how people learn to empower students to take ownership of their education and gain their knowledge and competencies, with special emphasis on the professional competencies as they are articulated in ABET a-k and Engineer 2020, in the context of learning engineering by practicing engineering side-by-side with engineers.

Iron Range Engineering is an extension of Itasca Community College Engineering in Grand Rapids, Minnesota. The ICC Engineering program, under the direction of Ron Ulseth, reached national prominence in engineering education through building learning communities, and providing an outstanding foundation in the first two years of an engineering program.
Today the IRE program is directed by Dr. Dan Ewert who comes to IRE after 19 years at North Dakota State University, the last 7 as a department chair. IRE has two distinct advisory boards - one from industry which provides significant input on how IRE meets the region's engineering and economic needs and another advisory board from academia that includes engineering education experts who provide guidance on learning outcomes, concrete expectations for when students have achieved competency levels, how students should be assessed with respect to learning outcomes, how progress with respect to these learning outcomes is made transparent to the students, what processes should be in place to support assessment, student learning, student development, and student growth, etc. The IRE Academic Advisory Board meets monthly to provide developmental guidance. Members are: Dr. Sheri Sheppard, Stanford University; Dr. Jeffrey Froyd, Texas A&M; Dr. Denny Davis, Washington State University; Dr. Thomas Litzinger, Penn State University; Dr. Edwin Jones, Iowa State University and St. Thomas University.

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<td>Understand (2)</td>
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**Figure 2.** Bloom’s 2D Taxonomy as utilized to chart student acquisition of technical competency through oral exams, design reviews, portfolio assessment, and the presentation of other evidence. At graduation an “A” student is expected to have an average 4.5 across all technical and professional competencies.
References


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Implementing Social Learning Strategies: Team Testing

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ABSTRACT
This paper describes how to provide collaborative learning opportunities and fast feedback on exam performance by adding a team component to examinations. The method is supported by research in collaborative and active learning pedagogy and has been applied to computer science courses ranging from first-year programming to graduate-level artificial intelligence. This paper relates the use of team tests in two different university settings, with a range of implementations. Furthermore, it offers suggestions for customizing the technique to fit a specific classroom environment.

1. INTRODUCTION
Finding the time and opportunity to incorporate active and collaborative learning in your classes can be challenging. Team testing is a collaborative learning activity with low implementation costs and multiple advantages for both students and faculty. Along with the obvious benefit of developing team problem solving and discussion skills, students receive fast feedback on their performance, the instructor spends less time reviewing the exam (in class and with individuals), and the classroom environment benefits from the added value placed on collaboration and reciprocal learning. This paper describes a number of variations on the team testing idea and discusses how factors in the course affect the type of team test to develop.

In a team test, the students complete an individual test paper as well as a group test paper. The individual component enforces individual accountability and allows the instructor to ask questions in formats that do not naturally benefit from a group discussion. The group component asks the students to evaluate others’ ideas and to synthesize a solution that incorporates the best ideas generated by the members of the group. Due to the need to compare and defend ideas, questions on the group test naturally elicit and evaluate higher-level cognitive functions like analysis, evaluation and transfer [1]. By doing so, team testing converts the evaluation environment into a learning environment. Depending on instructor goals, team tests can be structured to reinforce evaluation goals or learning environment goals.

Conventional wisdom holds that test periods are lost instructional time, but we recall that in our own experience as students, good exams often led to a more complete understanding of the material by forging relationships between domains and encouraging deeper insights. One student who participated in a team test reported, “You can collaborate and discuss what the general consensus of the answer is. … You [can] see why their answer might be more correct.” By leveraging the motivation that an examination conveys, team testing encourages active discussions between well-prepared individuals and fosters an ideal collaborative learning environment.
In addition to evaluating and encouraging higher levels of proficiency, team testing reduces the latency between evaluation and feedback. Exams give faculty an important opportunity to evaluate students, but they also serve to inform students of their progress and to point out areas where work is needed. Feedback should be timely to reduce exposure to content misperceptions and reinforcement of correct understandings [3, 10], but the time required to provide feedback to students is dependent on faculty time and the availability of grading support. The pressures on faculty time are discussed at length at conferences and meetings, and institutional budgets dictate whether grading support is available. In practice, this means that feedback is provided more slowly than desired, but team testing provides immediate feedback by exposing students to their peers’ understanding of the material and testing their ability to contribute to the group’s solution. By providing students with more timely feedback, team testing reinforces foundational knowledge that the remainder of the course requires.

In the next section, we describe the baseline team testing implementation. Section 3 provides the pedagogical theory supporting the idea, and Section 4 presents our experiences using variants on the baseline team testing implementation in the classroom.

2. IMPLEMENTING TEAM TESTING
2.1 Giving the Exam
The exam format depends on the ultimate goal of the group exam: evaluating content knowledge in a group context or creating a learning environment. To assess individual ability, an exam is given to each student. The individual exam is evaluated and typically forms the majority component of the student’s score. After the individual exam, there is a group component, which can either be a required part of the exam (evaluation goal) or considered a bonus (learning environment goal). Groups of 3 to 4 students collaborate on the group test. Larger groups reduce the impact of individual voices, and groups of two often suffer from a dominant (but not necessarily stronger) partner. The group exam can be given in the same class period, if time is available, or in the following period. Providing a gap between the two exams can be beneficial because students can shore up weaknesses in their understanding brought to light by the individual exam. However, not too much time should be allowed, since more misconceptions in understanding will be uncovered by the group exam than by the individual exam, and it is important to provide fast feedback.

Before the exam, students must prepare sufficiently to be ready to actively engage during the exam. Without adequate preparation, students may find it too easy to passively rely on the group consciousness and may not be capable of identifying gaps in their own knowledge during the discussion. To encourage individual accountability and active discussion during the exam, the students must follow two rules.

1. Each student must write some of the answers.
2. All students must agree on every answer submitted.

When there is a “hung jury”, students can be encouraged to record the top two positions with a supporting argument for each. This becomes an answer the group can agree on.

During the group exam, the instructor’s job is to facilitate discussion. As with any type of classroom problem solving, the instructor should move from group to group to keep students on task, to refocus or raising questions when necessary. If the goal is to facilitate learning rather than evaluate current knowledge, instructors can provide hints or feedback about trains of thought. At
the same time, the instructor can encourage individual accountability by drawing out students not actively participating or by keeping time and calling for groups to select a new student to record answers.

2.2 Setting the Questions
The individual component and group component should test the same domain of material so that the students gain the benefit of fast feedback. The questions on the two components may be the same or may differ in the level of proficiency exercised and evaluated. The type of questions featured on a group component will differ based on the level of the students in the class and the instructor’s learning objectives. The instructor may generate new questions for the group exam, but in many cases, asking the students to compare, analyze, or evaluate their answers from the individual exam enables a deeper exploration of the question in the collaborative context.

In early classes, where goals are often related to content knowledge and application within a defined setting and where students are less experienced learners, the questions will focus on factual or procedural knowledge and may not differ from the individual exam. Presenting the same problem on both exams prepares the students for discussion and encourages them to have a stake in a specific answer. Students at this level benefit from comparing answers and debating which is most correct [1].

For more advanced courses with mature learners, questions that focus on factual knowledge are less useful on the group exam as they do not foster in-depth discussion. The format favors open-ended problems that require students to evaluate and compare several possible solutions to reach a solution or that ask them to evaluate the context in which their knowledge is being applied.

3. SUPPORTING IDEAS
3.1 Theoretical Foundations
The theoretical foundation for this teaching method stems first from the work of Vygotsky who described a social constructivist framework for learning. In this type of setting, learning is enhanced by interaction with others beyond that which is possible individually [15,16]. Building community via discussion and collaborative learning can support the integration of academic and social experiences upon which student success has been shown to depend [14,18].

The ideas of active, collaborative, and reciprocal learning stem from Vygotsky's framework. In general, active and collaborative learning promote greater positive attitudes towards learning and the subject matter [6]. In reciprocal learning, students take turns teaching others. This is built into the structure of this approach, which strengthens student understanding of the material for both strong and weak students. Guided instruction [5], where scaffolding built by the teacher is reduced until the student has responsibility for learning, also motivates this approach: exams are used as a source of learning and content discussion, with students building community through their interaction with each other. Along the way, they build communication skills and communication abilities. In terms of team building, this approach has a low time-cost. By using the two simple rules presented in Section 2.1 to guide the process, we address the finding that students succeed best in teamwork when there are specific instructions about listening, leadership, consensus building and conflict resolution [7,12].

Even though collaborative learning has been supported by the National Science Foundation and recommended by the education community, it is still not widely practiced in engineering
classrooms [13]. When implementing active learning, faculty sometimes find it difficult to give up their role as controllers of knowledge [2]. However, giving an exam is an expected part of both traditional and active classrooms. As such, team testing may be a relatively comfortable step to take towards a more active classroom. Within computer science, team programming has been shown to enhance learning and community (e.g., [9]). Team testing can augment a class using team programming or provide similar benefits when used alone.

Feedback is generally considered important in learning and there is a growing body of work (and technology\(^1\)) related to providing fast feedback (e.g., [3,10]). Unfortunately, not much, if anything, has been published on the use of discussion as a fast feedback mechanism or the return speed of graded exams and assignments. However, structured discussion with peers is a well-known method for increasing engagement and enhancing learning [11,17]. Psychology research has shown that reinforcement, through punishment and/or rewards, is important to learning and that learning is easier when the reinforcement closely follows the action [4]. Team testing provides the reward of rapid feedback in two ways. First, it provides students with solution feedback and secondly, it provides feedback about their own performance and how it relates to the performance of their peers.

3.2 Justification
The time spent in collaborative learning is beneficial to the students because they are able to practice group problem solving with likely rewards. The students have spent time considering the problems before discussion, which encourages them to become more involved. In fact, team-testing discussions are amongst the most lively and energetic in our courses, in part because of emotional reactions to learning answers but also because each student is prepared for the discussion. The students are clearly connecting the content to a social learning environment.

Many teachers spend a significant amount of class time going over the correct responses to an exam, or worry that they cannot take the time to do this without losing content coverage. Rather than spend the same amount of time going over the exam, a team test allows students to discover, justify and own the answers. By having students spend time working through the exam with each other, the students become teachers, participating in reciprocal learning.

For planning teacher-to-classroom feedback, the group exams give a better picture of which concepts were globally missed or were difficult. As with any exam, this can be useful feedback about the teaching of the content, with even more weight because the results have been filtered through both individual minds and group consideration. When the teacher discusses the exam, the concepts missed after the group exam can be the focus, thus reducing faculty review time.

3.3 Benefits
One model of active learning separates "doing" from "observing" and differentiates between dialog "with self" and "with others" [6]. Group tests contain room for both types of dialog. First, the solo test forces the student to hold a dialog with self, with the instructor as audience. Next, the group section asks the students to enter into a dialog with others -- potentially with problems they have already considered and prepared answers for. While this dialog enhances learning, it

\(^1\) The Web-based Interactive Science and Engineering Learning Tool at Oregon State University is an example of fast-feedback technology [8].
also enhances the sense of community. Rather than prolonging a competitive evaluation atmosphere, a collaborative environment is available for students who prefer collaboration over competition.

In terms of feedback, after taking a team test, especially one identical to the individual exam, students leave the room knowing which of their answers are likely to be correct. One problem in test-taking is when smart students apply their own logic to problem solving but do not necessarily have the grounding knowledge. The logic may be solid but the answer is not correct. Discussion and skeptical questioning leads the group closer to a correct answer. As one student reported, “It was pretty productive because you could give an answer … but someone could give a rebuttal. … It would help you out in your understanding.”

Comparing performance on team and individual tests has made it possible to give students feedback not only on their content knowledge but also on their confidence in their knowledge. One student reported, “Having someone else’s word that something is correct feels like you are given more confidence in what is right and wrong.” Another was the only one of his group to get the answer correct on the individual test but was unable to persuade his peers to change their minds. After written and verbal encouragement, this student began to advocate his knowledge more strongly. At other times, we have observed students who are prepared but not confident in their knowledge be pleasantly surprised to find that they are at the same level, if not higher, than their peers.

4. TEAM TESTING IN THE CLASSROOM

Team testing has been employed in a total of nine different courses at two separate institutions: Minnesota State University, Mankato (MSU) and the University of Toronto Mississauga (UTM). The classes spanned the curriculum, ranging from first year programming to third year operating systems to graduate level natural language processing, so they display a variety of sizes (5-50 students), learners (novice to independent), and content (logical and algorithmic problem solving as well as design of large systems).

In this section, we introduce factors that affect the effectiveness of team testing and influence how it should be deployed. We report anecdotal evidence from our own experiences with team testing, relating students concerns and feedback wherever possible. The discussion focuses on the conditions in the classes that caused us to alter the team testing implementation.

4.1 Class Size

Team testing has been successfully used in classes of up to 50 students. However, the physical space should be large enough to allow space between the groups. Because discussion can get lively and faculty interaction is helpful, it works especially well in classes from 20-30. On the other end of the spectrum, it has been done with as few as 5-6 students. In this case, a single discussion group works, even though there are more than the preferred 3-4 students, because in very small classes, a group dynamic of discussion and problem solving often exists already.

4.2 Reward Systems

The most important variable that affects how students perceive team testing is its impact on their final grade. In its original form, we imagined team testing to be an opportunity to practice good discussions and to convert an evaluation environment into a learning environment. Students in a learning environment should feel comfortable practicing new skills, which suggests that the
evaluation weight should be low or nonexistent. At the same time, team tests work because the students come to the activity prepared and motivated, so we cannot simply eliminate the “test” component of team tests.

The original versions of team testing at MSU made the team test voluntary and offered extra credit for participating. In our experience, offering just 5% bonus credit on the individual exam causes an overwhelming fraction of students to remain for the team-test. The bonus points offer a tangible reward to the students, countering the stress that comes with exams and grades, while providing motivation to invest energy and preparation in a good outcome. As a result, students did not appear to feel stressed by the addition of the group component of the exam, but they did actively engage in the exercise.

In contrast, the academic culture at UTM made it difficult to offer bonus credit on an exam, so the group component of the exam was weighted as a small fraction (10%) of the overall exam mark. As a result, initial student reaction to the team test was quite different at UTM, with students expressing concern about being placed in a group with perceived “weaker” members and feeling stress preparing for the group activity. Instead of viewing the team test as an opportunity to collaborate, the students reacted negatively to a personal evaluation being affected by a factor outside of their control.

The instructors also perceived noticeable differences between the two exam environments. By offering extra credit for the team test, the MSU instructor was able to treat the exercise as a collaborative learning activity. She circulated among the groups, asked questions, and redirected groups that strayed off track. The UTM instructor, however, felt uncomfortable intervening in individual groups and felt that the exercise was an evaluation.

Nevertheless, in both cases, discussion within the groups was vigorous, and after the experience, students were pleased with the group exam. Both sets of students viewed the group discussion as a means for improving their overall mark, and many students enjoyed the activity.

4.3 Marking

The reward system chosen also impacts how the team test is marked. When assessing collaborative learning, the basic approach is to provide independent and interdependent assessment for group work [6]. The independent component of the exam maintains individual responsibility. If the reward is minimal and the focus is on learning, rather than evaluation, then the grades for group exams can be coarse, reducing grading time and ignoring small differences between groups. If the focus is on evaluation, then more care needs to be spent on the marking to provide formative feedback on the group’s effectiveness.

In our experience, due to the low weight of the group component and the focus on learning rather than evaluation, grading on group exams can be generous, not requiring a 100% correct answer to get full marks, making the reward positive for the students while still allowing for fast feedback. One student in particular was concerned that the other members of the group would not share his desire for excellence: “I really have a hard time doing the group thing as I strive to get the best grade and working in a group seldom allows for that opportunity.” A small reward provides motivation, and keeping the reward small enough to avoid further stress about the results of the group exam reduces complaints and classroom tension if a student feels he or she has been placed in a “bad” group.
4.4 Exam Composition
Team testing supports many different kinds of questions, and the relationship between questions on the individual exam varies depending on the instructor’s objectives. At both MSU and UTM, the instructors favored reusing questions from the independent component of the test. In our experience, relating the questions on the two exam components increases discussion since each student has spent some time thinking about the question and formulating an answer to which they have some emotional attachment. MSU had some success reusing exactly the same questions, and they found that solutions to group exam questions were noticeably stronger than typical answers on the individual exam. UTM tended to ask follow-on questions and saw similar results. Re-using questions also relieves one concern students reported about team tests – that the material on the group component would be significantly more difficult.

Regardless of the type of questions used, the group component should contain far less material than the individual component. When using a reduced set of problems rather than a full test, we found that students would delve deeply into related issues, starting discussions about theory and context that are rare in a regular classroom. In an electric circuit theory class, team testing was used on weekly quizzes. A short, two-problem quiz was given and then the same two problems were given to student pairs. After the first week, the team quiz was reduced to one problem, because students spent so much time discussing the application of theory. As a result, they were often able to show better understanding during this phase than on their individual quiz.

4.5 Instructor Time
Team testing does create some additional work for the teacher: creating a second exam and grading additional questions. This can be minimized by using the same (or at least related) questions on the group component and by coarsely grading the team work. Furthermore, marking time on the individual component is reduced since less feedback needs to be provided. Since the students have discussed the questions, they often better understand how they earned their grade, so students ask fewer questions about marking in office hours and by email. Instead, some student groups used office hours to continue the group discussion with instructor adjudication.

4.6 Exam Timing
When giving the team tests, the class structure made a difference in the method and the time allowed for team tests. When the class session is long enough (1.5 to 2 hours), immediately following the individual exam with the group exam works well. When there are recitation sections or labs, a portion of that time can be used for the team test instead of using extra lecture time. Giving a team test in the next class period, especially with time at the end for classroom discussion and questions also works, but it weakens the feedback link.

Students who have become accustomed to both the feedback and reward of group exams have asked for them at the final exam. In these cases, a slightly reduced exam time, e.g., from 120 minutes to 90 minutes, allows time for a team test as well as comprehensive coverage of course content. This gives students feedback they might not otherwise receive at the end of a term.

We have not yet tried giving a group exam before the individual exam. We feel this would increase exam preparation time since the group exam questions and individual exam questions would need to be more decoupled for a fair individual assessment. We are also concerned that discussion would be weaker, since the students would enter the group component with less preparation.
4.7 Group Formation
For any type of team work, the selection of the teams and the roles assigned to the team members has an impact on the team's success. The goal of group formation is to create effective groups, giving students a fair chance to do well while minimizing the problems that come with group work. We have used a wide variety of heuristics including student physical proximity (both close and distant), splitting up friends/lab partners/long term groups, and coupling weaker and stronger students. With one notable exception, the groups functioned well regardless of their method of creation. In that case, a student acknowledged as being exceptionally strong inadvertently dominated discussion, since his group was unprepared to challenge his ideas. Teacher intervention is required in this situation. The other students may be encouraged to enter the discussion by asking them to justify why they agree with the proposed solution.

At UTM, where the group component is a fraction of the test mark, some students requested that they be informed of group pairings before the exam to facilitate the formation of study groups. Despite some initial concern that releasing the pairings would result in the responsibility for studying material being split up among members of the group, we found that the individual exam led students to study all of the material. As a side benefit, some of the study groups that were formed because of the team test continued to meet later in the term.

We have not investigated assigning teams on a long-term basis but believe it would be an interesting avenue for future study. This approach would reinforce the social learning aspect and allow for more flexibility in negotiation of roles within a team.

5. SUMMARY
Team testing enhances student learning by providing faster feedback and using collaborative learning to develop higher order cognitive skills. It leverages student desire to thoroughly prepare for evaluation to increase engagement in a focused small-group discussion. In doing so, team testing converts an evaluation environment into a learning environment.

Team testing is a flexible idea which we have successfully implemented in many types of courses for a broad range of students, learning goals, and content foci. Since the exercise often repurposes material already generated for the individual component of the exam and decreases time spent reviewing exam solutions, we have found team testing to be a low-cost method for introducing collaborative learning into the classroom. More importantly, students have responded extremely positively – even going so far as to request a team test for the final exam!

6. ACKNOWLEDGMENTS
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7. REFERENCES


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Problem-Based Learning in Engineering Education: Reflections, Practices, and Challenges

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Abstract

This paper focuses on the utilization of problem–based learning (PBL) in an engineering program, and argues that implementation of problem-based learning needs to be placed in a context and must be developed with careful consideration of the social, economic, and ethnic diversity of the student population and the university academic culture and prevailing norms. The paper includes a brief history, selected PBL models, strategies to infuse PBL in an engineering program, and suggestions for redesigning classes and courses to catalyze change in the classroom environment through student engagement. The paper, also, addresses the potential difficulties that could arise during implementation of PBL, and argues for the need to conduct research in order to guide the process of transition from the old to the new paradigm.

Introduction

Achieving change via engineering education reform is a formidable challenge to any college of engineering, whether in North America or anywhere else in the world. In the past two decades, engineering educators have tried to implement relatively new methodologies in the classroom, primarily characterized by students’ active engagement or involvement in his or her academic work, resulting in better retention of new knowledge and acquisition of desirable personal traits. Any such method that engages students in the learning process is labeled as: “active learning” method. In essence, active learning requires doing meaningful learning activities in groups under the guidance of an informed and experienced teacher. As stated by Christensen et al (1991), “To teach is to engage students in learning.” The main point is that engaging students in learning is principally the responsibility of the teacher, who becomes less an imparter of knowledge and more a designer and a facilitator of learning experiences and opportunities. In other words, the real challenge in college teaching today is not covering the material for the students, but rather uncovering the material with the students (Smith et al 2005).

There are several strands of pedagogies of engagement under the umbrella of active learning methods that have received attention by engineering educators world-wide (Smith et al 2005; Prince 2004). These methods/approaches are known to increase students’ active engagement in learning and also, promote cognitive elaboration, enhance critical thinking, and contribute toward social and emotional development. The most utilized pedagogies in engineering
education today, and moving in the same broad direction, are: problem-based learning, cooperative learning, and collaborative learning (Smith et al 2005).

Problem-based learning (PBL) starts when students are confronted with an open-ended, ill-structured, real-world problem and work in teams to identify learning needs and develop a viable solution, with instructors acting as facilitators rather than primary sources of information (Prince 2004). There are numerous PBL teaching models, and are all equally valid and appear to work depending on factors and prevailing circumstances such as: 1) characteristics of the curriculum, 2) attitudes, knowledge, and skills of the academic staff, 3) underpinning academic culture of teaching and learning, and, 4) socio-economic background and abilities of the student body (Smith et al 2005; Prince 2004; Prince and Felder 2006). The paper examines different variations of PBL, selects suitable versions for potential adoption at the start, identifies essential elements of a well-structured learning strategy, and illustrates faculty role in implementing PBL.

Proven methodologies and knowledge generated elsewhere, if and when properly adapted, should make it possible for institutions to devise their own PBL models that meet their classroom setting, objectives, and aspirations. The paper sheds light on the nature of such models and argues for the need to conduct research in order to guide the process of transition from the old to the new paradigm, to ensure the vitality and currency of engineering education.

Active Learning: Definitions and Interpretations

It is difficult to come to grip with all the cited definitions, meanings, and interpretations of the term “active learning”, since different contributors in the field have interpreted some terms differently. However, by gleaming at the literature, it is possible to arrive at general consensus of what appears to be widely accepted definitions, and shed light on how common terms are used. Active learning is generally defined as any instructional method that engages students in the learning process. It is widely accepted that active learning requires students to take part in “pre-planned” learning-related activities, believed to spark and stimulate their learning, while in the classroom (Bloom 1956; Randolph 2000). These activities would include: reading, writing, solving problems, answering questions, participating in a discussion, etc.; and most important, students must be engaged in thinking tasks while actively involved. It is generally understood that during active learning, less emphasis is placed on transmission of information and more on developing students’ skills. Additionally, during an active learning cycle, emphasis is placed on students’ exploration of their own abilities, including: their thinking process, their value system, their intellect, and their courage to express themselves orally and in writing. Active learning is contrasted to the traditional lecture where students passively receive information from the instructor (Bloom 1956; Kolb 1984; Frederick 1987).

Collaborative learning refers to any and all of the instructional methods where students work together in small groups towards a common goal (Smith et al 2005; Prince 2004). It can be viewed as encompassing all group-based instructional methods, including cooperative learning (Frederick 1987; Millis and Cottell 1998). The central element of collaborative learning is collaboration vs. individual work (Prince 2004). Meta-analysis supports the view that collaboration does promote a broad range of learning outcomes. In particular, collaboration enhances academic achievement, and student attitudes. It also reduces attrition (Prince 2004). Cooperative learning is a formalized active learning structure where students work together in small groups to accomplish shared learning goals and to maximize their own and each others
learning. The most common model of cooperative learning in engineering is that of Johnson, Johnson and Smith (1991). This model has five specific elements: mutual interdependence, individual accountability, face to face interaction, interpersonal and small group skills, and individual assessment of group functioning (Johnson et al 1991). Although different cooperative models exist (Springer et al 1999), the core element in all, is the emphasis on cooperative incentives rather than competition in the promotion of learning. Some researchers view cooperative and collaborative learning as having two distinct historical developments and differing philosophical roots (Wales and Stager 1978). Despite differences and similarity of the two approaches (collaborative vs. cooperative), the fact is: that the core element of both is the emphasis on interactions, as the primary source of learning, rather than learning as individuals.

Problem-based learning (PBL) is an instructional method where relevant problems are introduced during the course to provide the context and motivation for the learning that follows (Mourtos 1997). PBL, by and large, is self-directed learning that helps develop positive student attitudes, foster a deeper approach to learning, and helps students retain knowledge longer than traditional instruction. It is appropriate here to mention that several approaches go under the name of problem-based-learning. These approaches to PBL have as many differences as they have elements in common, making interpretation of outcome rather difficult (Mayo et al 1993).

Before adopting a specific method of active learning, faculty members need to become familiar with the literature, and, in particular, the various strategies that promote active learning in the classroom. Despite familiarity with the literature, ambiguity and confusion may result, at times, from reading the literature; particularly when the effectiveness of any instructional method is compared with another method. Assessing “what works” requires looking at a broad range of learning outcomes, interpreting results carefully, and quantifying the magnitude of any reported improvement. To assess “what works” for a given set of conditions, the reader has to attain sufficient knowledge and familiarity with the subject matter (Prince 2004; Smith et al 2005).

Reported studies, by and large, tell us about success stories and seldom reveal what has not worked. Irrespective of how data, results, and interpretations are presented in the literature, faculty adopting a specific method with the expectations of experiencing similar results to those in the literature, should be aware of the limitations of any reported piece of research, i.e., such reports may not reveal all factors and details; and therefore, extrapolating without a thorough investigation could be misleading. This should not, by any means, discourage faculty from moving toward active learning; but rather intended as a “precautionary” observation, to new instructors: Not “to make too much” out of what they have read unless it is credible, thorough, and substantiated with facts and figures. Despite some pitfalls, engineering faculty should be strongly encouraged to examine the literature on active learning, including: the empirical research on its use, and the common barriers that may arise as a consequence of its application.

The author believes that learning “about” things is not enough to enable students to acquire the skills they will need in the future. Rather pedagogies of engagement, such as PBL, when properly implemented, will turn out the kinds of resourceful, engaged professionals that engineering practice needs. In the sections that follow, the author presents: i) relevant information on PBL, its practices and working models; ii) cooperative learning as a priori to PBL; and, iii) the lecture format, if and when combined with a selected active learning strategy, such as PBL- and its potential utilization in a traditional classroom setting.
**Problem-Based Learning: Historical Origin, Precepts, Practices, and Working Models**

The modern history of PBL begins in the 1970s at the medical school at McMaster University in Canada. Until recently, the PBL approach has flourished mainly in medical and professional schools. Slowly the sciences, have begun taking it up. PBL does not have a store of transferable techniques like cooperative learning, no "jigsaw," no "think-pair-share" or that sort of thing. Opinions vary on whether PBL should be implemented for entire courses or merely in parts of courses. Generally, advocates accept easing into it piecemeal, but favor course-long continuity.

In some ways what PBL is, seems self-evident: It's learning that results from working with problems. Official descriptions generally describe it as: *an instructional strategy in which students confront contextualized, ill-structured problems and strive to find meaningful solutions.* In other words, in PBL, learning results from the process of working toward the understanding or resolution of a problem. The problem is encountered first in the process (Barrows and Tamblyn 1980). Barrows (1996) identifies six core features of PBL: i) Learning is student-centered. ii) Learning is best accomplished in small groups. iii) Problems are the main focus for learning. iv) Problems are the vehicle for the acquisition of problem-solving skills. v) Teachers are facilitators of learning. And, vi) New information is acquired through self-directed learning.

The list of reasons for the deployment of PBL includes the fact that problem-based learning (PBL) ends up orienting students toward meaning-making over fact-collecting. Students learn via contextualized problem sets and situations. Because of that, and all that goes with it, namely the dynamics of group work and independent investigation, they achieve higher levels of comprehension, develop more learning and knowledge-forming skills and more social skills as well. This approach to teaching brings prior knowledge into play more rapidly and ends up fostering learning that adapts to new situations and related domains quickly and effectively. According to Woods (1994), PBL is suitable for introductory sciences and engineering classes – as it is for medicine- because it helps students develop skills and confidence for formulating problems they have never seen before. But where does PBL fit compared with all the other "learning methods"? Faculty hear about--"cooperative learning," "collaborative learning," and "active learning"? The proliferation of "learnings" and their attendant partisan camps invites the reawakening of long-standing faculty prejudice against educational fads and "methods." Even so, interest in PBL grows because not only does research show a higher quality of learning (though not a greater amount if "amount" equates with the number of facts), but problem-based learning simply feels right intuitively. It seems to reflect the way the mind actually works, not a set of parlor-game procedures for manipulating students into learning. Unfortunately, while there is agreement on the general definition of PBL, implementation has varied widely(Prince 2004). The large variation in PBL practices makes the analysis of its effectiveness a bit complex. Many studies comparing PBL to traditional programs are simply not talking about the same thing. As reported by Prince (2004), “For meta-studies of PBL to show any significant effect compared to traditional programs, the signal from the common elements of PBL would have to be greater than the noise produced by differences in the implementation of both PBL and traditional curricula.” Despite this, there are positive findings that do emerge from the literature, which support the following: i) PBL produces positive student attitudes, ii) provides more motivating and enjoyable approach to education, iii) improves long-term retention of knowledge compared to traditional instruction, and iv) promotes deep learning and problem-solving skills( Prince 2004).
A. Essentials of PBL: Problem–based learning is a philosophy that has to be adapted to the specific conditions and situation of an institution, and the nature of the specific field in which it is to be implemented. This is apparent in the different models of PBL implementation throughout the world. Therefore, there is no one–size–fits–all approach to PBL that can simply be implemented from one institution to another (Allen et al 1996). There are required steps that have to be mobilized at the start of PBL. At the start of learning in PBL is the selection of real problem(s). This is, in fact, the major driving force for learning. Effort and time dedicated to the selection of problem(s) is time well-spent and will eventually pay off. The problem(s) should be well crafted to engage and immerse students in learning new materials, as well as challenging existing knowledge, skills, and attitude. It is important to note that PBL is not only about giving problems and solving them in classroom, but it is also about creating opportunities for students to construct knowledge through interactions and collaborative inquiry (Allen et al 1996).

In PBL, the instructor is primarily a facilitator, whose role is to make the learning process visible, instead of making the content visible as in traditional lectures. Since assessment drives learning, the modes of assessment must also be modified to appropriately evaluate students for the desired outcomes that have been designed for the problem. For students to become problem solvers, they have to be actively involved in the learning process. When students are exposed to PBL for the first time, they must be guided, prepared, and motivated. It is not fair to expect students to readily have the skills for PBL, particularly when they have been exposed solely to traditional classroom environment. Therefore, students need to be prepared by exposing them to informal cooperative learning, where students are to work together to achieve a joint learning goal in temporary, ad-hoc groups that may last from a few minutes to one class period (Johnson et al 1998). Informal cooperative learning groups also ensure that misconceptions and gaps in understanding are identified and corrected. Using procedures such as informal cooperative learning guarantees their exposure to active and interactive methods prior to engaging in PBL.

B. Infusing PBL in the Curriculum: There are several strategies that may be utilized to infuse PBL in an engineering curriculum. The selected strategy depends upon: 1) the commitment of the institution, as a whole, to the process of deploying active learning schemes in general, and PBL in particular, 2) the readiness of the teaching staff, and 3) available resources, facilities, and support services. Table 1 illustrates three approaches to infuse PBL in the curriculum as suggested by Tan (2003): at the mega, macro and micro levels. Implementing PBL at the mega level requires commitment from the administration as well as from the teaching staff. As shown in Table1, an example of such an implementation is when students acquire their course work in its entirety, during the third or fourth year, by means of PBL. This would require a major revamp of the curriculum, along with realignment of program’s objectives and outcomes. At the macro level, certain courses in the curriculum are designated to be taught utilizing PBL, irrespective of who is in charge of the course. A macro implementation requires departmental approval and a firm commitment by the instructors teaching the course. Courses offered in multiple sections require coordination between instructors. The micro-level approach requires the least amount of resources. Its implementation is flexible, non-binding and amendable. This is where PBL can be used on a trial basis for certain topics in a selected course(s) within a certain time limit. Hence, this approach is highly recommended for trying out PBL for the first time.

C. The Start up of PBL: A gradual, step at a time approach, should be taken when infusing PBL in a program. At the start, steps should be taken to raise awareness and educate instructors
and students on key issues, techniques and potential hurdles that may arise when using PBL for the first time. During this initial period, it is advisable to form a central committee from experienced or semi-experienced lecturers, who are at ease with active learning strategies in general and PBL in particular, to facilitate the promotion of PBL at all levels of the academic community. This is a challenging time that requires patience, persistence, and social skills on the part of the committee members entrusted with the task of embarking on the process—where the committee will be moving against the tide in trying to plant the seeds of change. The major tasks that would be undertaken at this stage are: introduce PBL gradually and properly, convince teachers and students of its merits, and help train potential lecturers of when and how to use PBL. As instructors gain familiarity with PBL, they begin to develop their own techniques.

<table>
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<tr>
<th>Level</th>
<th>Range of Application</th>
<th>Details</th>
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| Mega Level  | PBL is applied to the entire 3rd or 4th year of a selected program                   | • Major revamp of curriculum  
• Needed commitment at all levels |
| Macro Level | PBL applied to two or three subjects in the 3rd or 4th year of a selected program     | • Need departmental approval and firm commitment from the lecturers teaching the selected subjects |
| Micro Level | PBL is applied to specific topics in a selected one or two courses                    | • Recommended for new starters  
• Will require proper coordination when implemented in courses with multi sections |

Table 1. Different approaches of infusing PBL

**Student Engagement Using Cooperative Learning Structures: A Priori to PBL**

As noted earlier, relying solely on the traditional lecture approach, no matter how competent the lecturer is, fails to engage students in learning; thus indirectly depriving students of learning experiences and opportunities that could only materialize utilizing engagement strategies. Under the umbrella of engagement strategies, there are numerous models available to select from, including the models predicated on cooperation - working together to accomplish shared goals. Within cooperative strategies, individuals seek outcomes that are beneficial to themselves and beneficial to all group members within the class (Johnson et al 1991; Smith et al 2005). The work by Johnson et al (1991) reveals that students exhibit a higher level of individual achievement, develop more positive interpersonal relationships, and achieve greater levels of academic self-esteem when participating in a successful cooperative learning environment.

Cooperative learning researchers and practitioners have shown that positive peer relations are essential to success in college. The positive interpersonal relationships, promoted through cooperative learning, are regarded by most as crucial to today’s learning communities. The underlying precept of cooperative and problem-based learning is “interdependence”. Cooperation is more than being physically near other students. It is the will to open up to others, exchange information and views with others, and accept the fact that working together is more beneficial to all involved in the exercise. For a cooperative learning to be successful, it is imperative that the following be integrated into the class activity (Lowman 1984; McLeod 1996):
- **Positive Interdependence** - Students should perceive the need for one another to perform the planned activity.
- **Face to Face Interaction** - Students should work together in planning, executing, and arriving at conclusions. They should share the work load, and share the credit.
- **Accountability** - Each student’s role and performance is to be assessed, and the results are those of the group (and for the group). Keeping track of the contribution and knowledge gained by each member could be monitored, as well, by either testing every student in the group, or by randomly selecting a group member to be tested and thus proxy for the group.
- **Sharing known skills** - Students who possess certain skills (examples: computer skills, laboratory skills, data reduction skills, presentation skills) should be willing to pass it on, and/or share it with their group members.
- **Collaborative Skills** - Groups cannot function effectively if members do not have (be willing to learn) or use some needed social skills. These skills include leadership, decision making, trust building, and conflict management.
- **Monitoring Progress** - Groups need to discuss amongst each other whether they are achieving set goals; they also need to prioritize the scheduled activities, solicit advice and assistance with the consent of the instructor, and maintain working relationships among the members.

Success in implementing problem-based cooperative learning is attributable, in large measure, to: proper planning, efforts, dedication, and foresight of the instructor. Experience definitely is a major factor. A proper start for instructors wanting to try any of the active learning strategies for the first time (including problem-based cooperative learning) is to step into it gradually, and to seek feedback as to how the course is going and how the students feel about it. Also, he/she can tap into documented sources, and discuss planned activities with experienced colleagues.

### The Lecture Format together with Active Learning Strategies

When asked why he lectures, one faculty responded: “*It is tradition. It was part of my training, and seems to dwell in me and seems like what I should be doing. I feel guilty when I am not lecturing*” (Creed 1986). This candid statement suggests one of the great dilemmas faced by all who teach at the post-secondary level. Lecturing is virtually synonymous with teaching. It was the dominant method by which we were taught - and it is the method by which most of us teach. When discussing potential change in current teaching–learning strategies, many faculty members become defensive, and discussions may quickly degenerate into heated debates where sides are clearly drawn. Over-exuberant advocates of *active learning* have, unfortunately, not been able to persuade the majority of those who have grown accustomed to traditional teaching methods. More efforts and better approaches in persuading the traditionalists appear necessary. The challenge is to choose a suitable method at the appropriate time. Understanding the *pros and cons* of the lecture method is a helpful start.

Lectures have a number of characteristics that does make them, for the right subject matter, desirable in the classroom (Creed 1986). It does, to a great extent, depend on the abilities and experience of the lecturer. An able and committed lecturer can accomplish the following:

1. Relate the material proficiently and effectively, in a manner that reflects lecturer’s personal conviction and grasp of the subject matter;
2. Provide students with a thoughtful, scholarly role model to emulate;
3. Supplement the subject matter with current developments not yet published, or interject lecturer’s own views derived from his/her own experience whenever applicable;
4. Organize material in ways to meet the particular needs of a given audience;
5. Efficiently deliver large amounts of information when the need arises without confusion;
6. Underscore key points, simplify complexities, illustrate with facts and figures.

In addition, lectures are presumably cost-effective in that they can reach many listeners at one time, they present a minimum threat to students in that they are not required to actively participate, and they provide an advantage for those students who find learning by listening enjoyable (Creed 1986). As most students will attest, not all lectures or lecturers achieve these goals. Research findings suggest that a number of identifiable attributes must be implemented to make a lecture truly effective. For instance, students remember material presented at the beginning of a lecture better than information presented in the middle or at the end of the lecture. Also, the effectiveness of the lecture varies inversely with the difficulty of the material presented, and listeners retain factual material better when presented in short sentences rather than in long sentences. These characteristics presume that the lecturer is an enthusiastic and knowledgeable scholar. But, we realize that most campuses have a few that fit this description, and could keep most students interested during the formal 50- minute lecture. Even if it is assumed that most engineering lecturers possess these necessary characteristics, research has shown that the exclusive use of the lecture in the classroom constrains students’ learning.

An important problems associated with total reliance on the lecture method is the inability of most students to listen effectively to any lecturer, no matter how skillful, over a sustained period. Ten to 20 minutes into the lecture, however, confusion and boredom set in and assimilation fell rapidly, remaining at a low state until a brief period toward the end of the session when students were revived by the knowledge that the lecture would soon be over (Penner 1984). There are too many reports in the literature on lack of concentration by the audience, even when the lecturer is brilliant and the attendees are highly motivated, including medical students (Bonwell 1991). When it comes to “note-taking” during a 50 minute lecture, research has shown that students have noted 40 percent of the content presented during the first 15 minutes, 25 percent of the total content in a 30 minute-period, and only 20 percent during 45 minutes (Penner 1984). Even with competent students listening to an interesting topic, several problems remain, including:
1. Course content is often presented via lecture in unorganized and uneven fashion. This makes it difficult for students to determine the most important aspects of the lecture;
2. Many college students do not know how to take effective notes. Although formats for effective “note-taking” have been identified. The fact is: that “note-taking” is seldom taught;
3. The listening, language, and motor skill deficits of students make it difficult to identify important lecture content and write it correctly and quickly enough during a lecture;
4. Instructors sometimes get off-track from the primary objectives of the lecture. Professors—especially those who really know and love their disciplines—are famous for going off on tangents. Although getting off-track breaks the monotony, it could make it difficult for even the most skilled note-takers to determine the most important content.

For those instructors who would like to go beyond the traditional methods of lecturing, a number of effective strategies promoting active learning are available to choose from. If a faculty member is hesitant about selecting one or more of these active learning strategies because some questions exist about its comparative effectiveness with the lecture method, he or she should
consider the following: research has shown, beyond the shadow of doubt, *that these strategies do deliver content as well as lectures while providing diverse presentations that enhances students’ motivation and achievement, and helps in building up desirable personal traits.*

**Concluding Remarks**

On the whole, the intended move towards encouraging instructors to adopt *problem-based learning* (PBL) seems farfetched and difficult to accomplish, especially in the initial stage. This is because time is needed for those undertaking the task to be trained to implement and gain the experience necessary to move the process forward. Time is also needed for other stakeholders to be convinced and to provide the support needed to prescribe the change. Most importantly, those promoting the change must be able to show that PBL is effective for engineering education.

It is highly recommended that an Active Learning Taskforce be formed of experienced faculty, to initiate, infuse, and oversee the progress made. Their determination, patience, and resilience are required to successfully promote college-wide implementation of PBL. Nevertheless, with clear intentions, goals and plans of action, coupled with support from the highest level of the University’s key personnel, the Taskforce and other core groups, should be able to move the process forward. Success would almost be guaranteed, when a well-coordinated university-wide implementation of PBL is underway in other colleges of the University.

**Bibliography**


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Use of Student Surveys to Improve Efficacy of Lab Experience and Guide Lab Development

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Abstract

One way to refocus the importance of hands-on education is to allow students to have ownership of their lab experience so that, in time, the lab curriculum is tailored to their needs and wants. This paper discusses the use of student surveys to help improve the efficacy of lab experience for undergraduate Civil & Environmental Engineering students at the University of Iowa. At the end of each semester, students complete a survey to evaluate the condition of the lab, curriculum, and equipment, what they felt worked well and not so well, and to note any tests or materials that were not done which they would have liked to do. This evaluation was then summarized and used to guide further development of the lab space and the curriculum. The use of the surveys together with significant equipment upgrades and purchases has led to a substantial improvement in the lab experience for the students.

Introduction

As a “practical” profession, it can be argued that engineering is intrinsically hands-on, but at the undergraduate engineering education level, a solid laboratory experience is often met with several challenges. Feisel and Rosa (2005) point out that engineering laboratories often lack clear objectives while engineering curricula have become more theoretical with a shift from experimental activities to computational simulations due to the relatively high cost of purchasing and maintaining laboratory equipment as opposed to the relatively low cost and increasing realism of modeling software. However, there are many arguments for adding and strengthening laboratory components in the undergraduate curricula. For the students, laboratories present an opportunity to take concepts and formulae from lectures and textbooks and test them in a controlled environment. In some cases, such as designing, mixing, and testing Portland cement concrete, the lab experience may be the only opportunity a student has to work intimately with a material system before heading off into the workforce. The lab experience also provides an opportunity to establish cooperative approaches to problem solving, completing tasks, and conveying results via reports and presentations, all of which are imperative for the workplace, but difficult to gain in a lecture environment (Felder, Woods et al. 2000; Edward 2002). Furthermore, in a laboratory environment where the number of students is usually smaller and the setting less formal, it is easier to accommodate a variety of learning styles (Felder and Silverman 1988). From an instructor’s perspective, laboratory activities offer a natural venue to achieve deeper learning in accordance with Bloom’s Taxonomy (Bloom and Krathwohl 1956):

- Knowledge: students will be able to recall information from lecture
- Comprehension: students will be able to explain concepts to each other
• Application: students will be able to solve problems using concepts/formulae
• Analysis: students will be able to develop experimental plans and troubleshoot equipment
• Synthesis: students will be able to design and conduct experiments
• Evaluation: students will be able to discuss and critique procedures and results.

One way in which to help streamline hands-on laboratory education in terms of objectives, equipment, and products is to make the lab activities as relevant as possible to their interests, goals and future careers. This involves giving the students ownership of their lab experience. The concept of student ownership has many facets, including letting students plan educational objectives and activities, select educational materials, teach other students, and reflect critically on their expectations and experiences (Fletcher 2008).

One of the objectives of the civil and environmental curriculum at The University of Iowa is to produce graduates who have a strong foundation of scientific and technical knowledge and are equipped with problem solving, teamwork, and communication skills that will serve them throughout their careers. To this end, there are five stated outcomes pertaining to this objective that can be tied to hands-on experimental education (CEE 2008):

• The ability to apply knowledge of mathematics, science and engineering in their chosen fields within civil engineering.
• The ability to design and conduct experiments, and to analyze and interpret experimental results.
• The ability to work as members of multidisciplinary project and/or research teams, and have an understanding of leadership in teams and organizations.
• The ability to identify, formulate, and solve engineering problems.
• The ability to communicate effectively in written, oral, and graphical forms.

At The University of Iowa, a reorganization of the undergraduate Civil & Environmental Engineering in 2005 included combining a 3.0 semester-hour (s.h.) senior level elective lecture course entitled “Construction Materials” with a 1.0 s.h. required laboratory class entitled “Experiments in CEE” into a single required 3.0 s.h. lecture and lab course entitled “Civil Engineering Materials”. This newly integrated course required lab experiments that would tie in conceptually and chronologically with the lecture. At the time, the lab space required almost complete redevelopment after a building renovation had eliminated a high-ceiling structural testing laboratory and movement into a space with 15-foot ceiling heights. The re-located Structural Testing Laboratory (STL) could not accommodate large-scale structural testing capabilities but did contain a compression test machine, a small universal test machine, and a torsion machine. During the first two years the course was taught, the universal test machine was used to test a variety steel and aluminum specimens that had undergone different heat treatments in monotonic tension. The compression test machine was used in compression and split-cylinder tension testing of Portland cement concrete specimens. Finally, hot-mix asphalt was tested in a separate Asphalt Research Laboratory.

As a preliminary assessment of the effectiveness of the laboratory experience of the Civil Engineering Materials course and to help direct both the development of the laboratory and the experiments performed in the lab component of the course, an open-ended survey was given at the end of the semester. The survey was given to obtain student reflections on their experience.
with the understanding that their feedback would be used to guide both the laboratory and experiment development for subsequent teachings of the course. An ulterior motive of the surveys was to give the students a sense of ownership of their laboratory experience - that their connection to the laboratory goes beyond the course and the semester.

Civil Engineering Materials End-of-Semester Survey

In the present curriculum at The University of Iowa, “Civil Engineering Materials” is a junior level course that provides a survey of common materials, their behavior and analyses. The course is offered every spring semester with a typical enrollment of up to sixty students, which breaks down into four laboratory sections of about fifteen students each. The laboratory component of the course is concentrated on testing four material systems: structural metals, Portland cement concrete (PCC), hot-mix asphalt (HMA), and fiber-reinforced polymer (FRP) composites. At the end of each semester that the course is taught, each student receives a survey consisting of open-ended questions, allowing them to critique the experiments they conducted and help direct the further development of the lab by suggesting additional experiments and materials. At present, completion of the surveys has been voluntary with 39 responses in 2005, 20 in 2006, 21 in 2007, and 13 in 2010. Data is not available for 2008 and 2009. The survey questions are listed in Table 1 along with typical responses over the past five years.

Table 1. Lab survey and typical responses.

<table>
<thead>
<tr>
<th>End-of-semester Civil Engineering Materials Survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What did you like about the labs?</td>
</tr>
<tr>
<td>• Group size/participation (3/20 – 2006, 2/13 – 2010)</td>
</tr>
<tr>
<td>• “Helped me understand what we were talking about in the class.”</td>
</tr>
<tr>
<td>• “Hands on. Got to see what we had been talking about since [mechanics of deformable bodies]. (i.e. ultimate strength, modulus of elasticity)”</td>
</tr>
<tr>
<td>• “Making [stress and strain] curves for metals.”</td>
</tr>
<tr>
<td>• “Good hands-on experience, introduction to computerized testing equipment.”</td>
</tr>
<tr>
<td>2. What did you not like about the labs?</td>
</tr>
<tr>
<td>• Some experiments did not sync with lecture (2/39 -2005, 1/13 – 2010)</td>
</tr>
<tr>
<td>• Some labs (i.e. tension test) could be combined (4/39 – 2005, 3/20 – 2006)</td>
</tr>
<tr>
<td>• Giving presentations (2/13 – 2010)</td>
</tr>
</tbody>
</table>
3. Of the materials that we did test, are there any other tests that you would have liked to conduct?
   - Testing of structures (2/21 – 2007)
   - Different annealing processes and their effects (1/21 – 2007)
   - Torsion testing (1/13 – 2010)
   - Charpy impact test (1/13 – 2010)
   - Strength of aggregate (2/13 – 2010)

4. Are there any tests that were conducted that you thought were not beneficial?
   - Air-entrainment of concrete (1/13 – 2010)
   - Asphalt binder testing (1/13 – 2010)

5. What materials were not tested that you would have liked to?
   - Polymers (4/39 – 2005)
   - Other types of asphalt (2/20 – 2006)

6. Were the supplied written materials (lab manual) helpful in conducting the tests?
   - Could use more detail (2/39 – 2005)

7. Was there enough background to the tests included in the lab write-ups?
   - Could use more basic knowledge about how the tests worked (1/20 – 2006, 1/13 – 2010)

8. Any other comments?
   - “One of the few class labs I liked” (2005)
   - “Best lab so far at school” (2005)
• “Organized/fun lab!” (2006)
• “… field trip to see how things are done on the jobsite would be good…” (2006)
• “Field trip – definitely” (2007)
• “[Labs] were interesting and I could see the direct correlation to the lectures” (2010)

Discussion

It is noted that since this preliminary survey is open-ended, responses are difficult to summarize and risk being somewhat subjective. With that being said, the results of the survey have been very beneficial in gauging what has and has not worked in the laboratory. For example, since many students have pointed out issues with equipment, emphasis is made to remedy the problems before the start of the next academic year. While it is the rare student who enjoys writing lab reports, survey responses are used to help adapt the lab manual and the lab report guidelines to help make the lab reports clear, concise and relevant. Most importantly, the results of the survey have helped drive the renovation and organization of the lab over the past five years. Over the summer of 2005, money invested in the STL was used to purchase three new computers, LabView software, and National Instruments hardware, and a single degree-of-freedom shaker table. Two additional universal test machines were brought in from other laboratories. During the next two years, several lab stations were setup:

• **Tension test station:** A small Tinius-Olsen universal test machine instrumented to a computer using NI hardware with LabView software. Stress and strain data are acquired and plots are shown real-time on the screen. Current experiments test steel, aluminum, and composite materials.

• **Torsion test station:** A Tinius-Olsen Torsion machine instrumented to a computer using NI hardware with LabView software. Shear stress and shear strain data are acquired and plots are shown real-time on the screen. Current experiments test steel and aluminum materials.

• **Concrete testing station:** A Satec compression test machine is instrumented to a computer where machine control and data acquisition is done with Partner software. Stress and strain data are acquired and plots are shown real-time on the screen. Current experiments testing capabilities include compression, split-cylinder tension, three and four point bend tests. Current experiments test Portland cement concrete.

• **Structural component testing station:** a large Tinius-Olsen universal test machine that has been modified to apply loads to common structural components such as wide flange beams, trusses and frames using a variety of connections (i.e. pins, rollers, fixed-end). A computer with LabView is used to collect stress and strain data via a load cell and strain gage rosettes.

• **Shaker table station:** A single degree-of-freedom (1DOF) shaker table is used in dynamic analysis of structures. A computer with LabView is used to control the shaker table as well as collect data.
As the survey results have helped to direct the development of the STL, additional opportunities for hands-on engineering education have been fostered. In the spring of 2008, new equipment was purchased, including vibration analysis hardware and software and an optical strain gage system for real-time measuring capabilities with an emphasis on structure health monitoring (SHM). This has led to the development of a new course, Structural Modeling and Health Monitoring (SMHM) that was first taught in the spring of 2009. This course includes having students apply various types of strain gages and accelerometers to beams, trusses, and frames in order to compare the behavior of “real-life” structures to their corresponding finite element models. In addition, the laboratory has been used as a central location where demonstrations are developed for other courses such as Statics, Mechanics of Deformable Bodies and Fundamentals of Vibrations.

**Future Directions**

While the investment in time and money for the structural teachings labs has been substantial, the faculty has recognized the importance of the lab experience and has outlined several goals and directions. While LabView is used to collect data, it also has the ability to control the equipment. A minor complication to this is that many of the testing machines are older and require some electrical retrofit in order to allow computer control. Within the next year, a goal is to have all of the machines controlled by computer, allowing for possible “closed-loop” testing. Other projects include developing a course in which students will gain instrumentation experience by obtaining real-time data from local civil engineering infrastructure such as buildings and bridges.

Since the student surveys have been recognized as an important factor in addressing the needs and wants of the undergraduate laboratory experience, the survey, itself, needs further development. The survey should be modified to tie in more explicitly with individual lab objectives. Further, completion of the survey up to this point has been voluntary, and with the end of the semester rush, return has less than optimal. Future surveys should be made mandatory and structured in a way so that results are more objective. Finally, additional efforts could look to the vast network of alumni to determine how the hands-on instruction they received relates to their careers in engineering.

**Conclusion**

In order to help evaluate the efficacy of the laboratory component of Civil Engineering Materials, students were given an opportunity for the ownership of their lab experience through an open-ended survey. Results of the survey have had two main outcomes: (1) assessment of what did and did not work in the lab experience; and (2) direction of lab objectives, renovation, organization, and equipment purchases. The use of student surveys has been very beneficial in the enhancement of the undergraduate laboratory experience and should be further developed to help direct the hands-on education necessary to produce engaged and competent engineers.
Acknowledgements

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References


Integrating Hardware and Software Filtering in Embedded System Audio Data Processing: An Embedded Systems Course Project

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Abstract

This paper describes a course laboratory project for an embedded systems course. The project is intended to provide a real world embedded development task for the students to accomplish in a few week time using a predefined microcontroller and suggested circuit components. The task combines audio sound recording, off-processor storage and filtered audio data replay. The paper includes a brief summary of the course concepts and the particular topics related to the project, an overview of the project goals and suggested circuit and constraints and a possible solution to satisfy the task goals including a complete circuit design and software design. Finally, the paper concludes with a discussion of the in-class results of assigning this project to students, their feedback and possible future changes to enhance the learning experience in future offerings.

Project Summary

The project was designed around a target processor (microcontroller) from Microchip Co. to exercise the student's knowledge of the SPI (Serial Peripheral Interface) protocol and its implementation in the processor. In addition, the students were required to apply knowledge of digital and analog circuit design to complete a working demonstration. The embedded systems course gives the students an opportunity to put to practice the skills gained through previous coursework and electronics laboratory experimentation. This paper describes the course concepts associated with the audio system project, the project itself including the instructor's example hardware design intended as a possible interfacing option for the students, and some conclusions based on multiple course offerings of this project.

The embedded systems course covers many topics concerning the interfacing of sensors, actuators, peripherals, I/O (Input/Output) and communication methods within an embedded design. The course is conducted using a combination of lecture material covering embedded hardware and software theory as well as project based laboratory experiences. This provides an environment for project teams to apply the concepts from lecture taking design specifications from prototype design to implementation, test, and
demonstration. All projects have a required demonstration to showcase the results from team activities.

The audio project discussed in this paper is described below. All students are provided with the following project specifications:

**Project Description**

This project involves the construction of an external memory circuit using a low voltage Flash memory device. The memory interface is implemented using the Serial Peripheral Interface (SPI) protocol. A circuit diagram is included. The goal of the project is to enable data recording and play back for digital and/or analog data at frequencies up to 3 kHz. Each team has two options for the completion of the project, one of which must be completed. All graduate students must complete Option 2.

**Option 1:** Record variable frequency logic data (50% duty cycle) for five seconds with signal frequencies up to 3 kHz. Then, play the recorded data through the protoboard speaker using appropriate interface circuitry. An eight Ohm speaker requires a driver and cannot be adequately driven directly from the pic18f8680 processor. The record and playback interface must occur using the USART peripheral and HyperTerminal. All circuits must be powered using the SSE 8680 5V source.

**Option 2:** Record analog voice data (Note: The diagram for a possible microphone interface circuit is available) for five seconds. Then, play the recorded data through the protoboard speaker using sufficient filtering and interface circuitry. An eight Ohm speaker requires a driver and cannot be adequately driven directly from the pic18f8680 processor. The record and playback interface must occur using the USART peripheral and HyperTerminal. All circuits must be powered using the SSE 8680 5V source.

These specifications do not come with many restrictions and this is to allow the student project teams to add an element of design to the project completion. For example, the project discussed in this paper explicitly requires consideration the SPI protocol and its implementation in the target processor, but also required the students to research (on their own) viable options for efficiently storing digitized data with a limited bandwidth and converting the stored data back to sound. In particular, Option 2 requires the storage and playback of voice data. This requires the students to research the appropriate sampling frequency, data storage event frequency, data filtering and playback. The students were not required to complete the data conversion (digital to analog) for the playback using a hardware converter (Note: The target PIC microcontroller does not have a built in D/A hardware converter.) but were free to determine and implement possible hardware and/or software solutions. The instructor example solution will describe a software conversion solution.

The target processor is one of the class of PIC18 8-bit (data path) microcontrollers available through Microchip Co. The engineering and technology department has
utilized PIC microcontrollers for multiple courses and laboratory experiences as well as encouraged their use in senior design experiences due to their low relative cost, freely available student versions of a fully integrated IDE (Integrated Development Environment) and because of the department's investment in programming hardware used to write/erase the onboard Flash memory. The embedded course covers an overview and tutorial of the Microchip IDE software package called MPLAB. The IDE allows development in Assembly Language as well as C-programming. The course is taught emphasizing programming in C and the solution code described in the paper is written in C. The project requires interfacing with a SPI Flash external memory device (M25P16). The device provided is from STMicroelectronics however, compatible devices can also be used with possibly small changes to the software. This device was specifically chosen for four reasons: 1) It is an SPI interfaced memory device requiring the implementer to carefully read the specifics of the datasheet, 2) It can be operated at speeds which exceed the instruction rate of the target microcontroller so that the target processor is the speed limiter for the project, 3) It is a 3.3V device requiring care to interface with the target processor which is a 5V device, 4) It is a surface mount device (SOIC) requiring the student teams to exercise surface mount soldering. To power a 3.3V device, one can use a 3.3V voltage regulator. The LT1121 was chosen based on the current sourcing capability, robustness and the low dropout capability. As with the SPI memory device, this device was chosen with the hope that the limitations associated with the project designs/prototyping are due to those aspects of the project controlled by the students.

The diagram below was provided to the students along with the project description. The top circuit is used only with the Option 2 portion of the project and it is a typical combined level shifting signal gain design found in the literature and within many electronics suppliers application documentation. This design was influenced by the WM Series Electret Circuit available on the www.Digikey.com website. The bottom circuit was influenced by the information in the datasheets for the memory and regulator devices. Resistors are used between all signals coming from the target processor to the SPI memory device to drop the excess voltage from the target processor. This is not the only way to provide an interface and in fact is not very robust since the current draw of the SPI memory device varies between different manufacturers and the resistor values need to be configured specifically for the specific device. There are devices available which specifically facilitate this interface such as 74LVC4245 Octal Bus Transceiver and level shifter. Alternatively, one could use opto-isolators to interface 5V to 3.3V I/O. Other options are also possible and the students were encouraged to attempt other implementations.
Figure 1: Circuit template available for use by students during the project.
For the software development, MPLAB includes many built-in functions to simplify the software development when using processor peripherals, however this is usually not encouraged by the instructor in an effort to instead encourage the students to consider the specific registers involved and to understand the functionality of the peripherals at the register level. The memory device is interfaced using the SPI (Serial Peripheral Interface) protocol. The specifications and functionality of this protocol is covered in the embedded systems course and the target processor does include the SPI protocol with assigned pins for three or four wire interfacing. The SPI can be configured to interface with (slave) devices in parallel or in series. The processor assigned slave select pin toggles at the beginning and end of all bytes sent through the interface. As with most applications, one size does not fit all. The memory device requires this toggling only at the beginning and end of a packet of bytes. Inter-packet toggling causes improper responses from the memory device. To get around this problem, a supplemental pin is designated as the slave select and the processor assigned slave select pin is not used. In the instructor solution, PORT C pin 2 was used (Refer to the Appendix for details). The processor facilitates the transfer of bytes through straightforward register bit toggling.

The project does require the careful sequencing of the proper bytes to initiate stored data transfer.

Replaying the stored data through a speaker required the students to implement appropriate driver circuitry. Possible options include a simple filtered transistor-based driver or an amplifier circuit designed around a device such as the LA4510 power amplifier. In addition, to complete Option 2 of the project, the data is stored digitally but must be delivered to the speaker as an analog signal. Possible options include an external D/A interface (The target processor does not include an on-board D/A converter) or internal approximate D/A conversion coupled with an external filter. This could be implemented by generating a sequence of logic zeros and ones each having duration a function of the digitized sample magnitude. There are multiple functions which could be used. Two possible functions are shown in the figure below.

![Digital sample, S_t with 8-bit encoding has a range from 0-255. Assume sample rate during recording was f_s = 1/T Hz.](image)

Figure 2: Example D/A conversion sequence.
The instructor solution utilized the method (a) from Figure 2 with each stored sample being translated into two digital bit segments. The first segment is logic one and the last segment is logic zero. The combined pulse width of the two segments taken together remains constant, but the first segment pulse width varies in proportion to the stored sample magnitude. See the Appendix for details.

Results

This project was well received for a few reasons. First, the students are challenged with a hardware circuit design which is simple but requires soldering SOIC devices. Second, the project relates to a very familiar application to the students, namely MP3 players. Third, this project integrates user I/O, external memory, flexible data storage and some data processing requiring the students to consider multiple design options for implementation. This allowed the students some flexibility in their design and presented a competitive aspect to the project.

The students found the hardware aspects of the project to be understandable, but challenging. Many student groups assumed their interface design would work “out of the box”. The project did challenge their circuit diagnostics skills. The instructor did provide a basic program which could be used to test the memory device interface implemented by each student group. As with most embedded system projects, problems can surface in the hardware and software portions of the design. Isolating these problems is critical in yielding proper functionality. The students were encouraged to design their own test software for projects like this as part of a systematic approach to design verification. This project has been offered multiple times over the span of three years. The last offering utilized an alternative processor, but with the same project goals. Most student groups were at least partially successful in the completion of the project and felt the experience was valuable.

References


Student versions of MPLAB IDE and MPLAB C18 compiler is available from the [www.microchip.com](http://www.microchip.com) website.
Biography

VINCENT WINSTEAD
Dr. Vincent Winstead is an associate professor in the electrical and computer engineering and technology department at Minnesota State University, Mankato. He completed his Ph.D. degree at the University of Wisconsin, Madison in Electrical Engineering.

Appendix:

```
#include <p18f8680.h>
#include "lcd.h"
#include "serial.h"

void high_isr(void);

char LF = 0x0a; // line feed
char CR = 0x0d; // carriage return
char send_WE = 0x06; // write enable
char send_CE = 0xc7; // chip erase
char send_WS[2] = {0x01, 0x02}; // WEL set, write status register address and data for global memory access
char read_ID[6] = {0x90, 0x00, 0x00, 0x00, 0x00, 0x00}; // read ID address and placeholder bytes
char read_ID2[4] = {0x9f, 0x00, 0x00, 0x00};
char read_data[4] = {0x03, 0x00, 0x00, 0x00};
char read_status = 0x05;
char send_PP[14]; // page program command, address and data bytes
char PP_A1 = 0x00; // store at memory locations 0x000000 - 0x00000A
char PP_A2 = 0x00;
char PP_A3 = 0x00;
unsigned char rec_data[10];
unsigned char TEMP_info[20] = {0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0};

unsigned char S_Rec, Temp_Rec[2], Play_loop;
int i;
unsigned long Add_Start, Num_Addresses;
unsigned int Record_Seconds=0, Record_count=0;

rom char *msg1 = "I am very happy.";
rom char *blank = "                   ";
rom char *msg_complete = "Operation Complete!";
rom char *msg_page = "Page ";
rom char *msg_write = " written";
rom char *C19200 = "Connection established at 19200 baud...";
rom char *Windbond = "Winbond Serial Flash Device Detected";
rom char *P80 = "Device ID: W25P80 (8Mbit or 1MByte)"
rom char *P16 = "Device ID: W25P16 (16Mbit or 2MByte)"
rom char *EC = "Enter command (0=exit, 1=record, 2=playback, 3=display, 4=delete, 5=stats): ";
rom char *NS = "Number of seconds (1-200): ";
```
void Data_To_M25P80(char xc)
{
    char temp;
    PORTCbits.RC2 = 0; // CS active low
    SSPBUF = xc;
    while (!SSPSTATbits.BF);
    temp = SSPBUF; // clear BF flag
    PORTCbits.RC2 = 1; // end of transmission
}

void RepeatedChar_To_M25P80(char *ptr, unsigned char length, char xc, unsigned int num)
{
    char temp;
    PORTCbits.RC2 = 0; // CS active low
    while (length)
    {
        SSPBUF = *(ptr++);
        while (!SSPSTATbits.BF);
        temp = SSPBUF; // clear BF flag
        length--;
    }
    while (num)
    {
        SSPBUF = xc;
        while (!SSPSTATbits.BF);
        temp = SSPBUF; // clear BF flag
        num--;
    }
    PORTCbits.RC2 = 1; // end of transmission
}

void StrData_To_M25P80(char *ptr, unsigned char length)
{
    char temp;
    PORTCbits.RC2 = 0; // CS active low
    while (length)
    {
        SSPBUF = *(ptr++);
        while (!SSPSTATbits.BF);
        temp = SSPBUF; // clear BF flag
        length--;
    }
    PORTCbits.RC2 = 1; // end of string transmission
}

void StrData_To_From_M25P80(char *ptr, unsigned char s_len, unsigned char r_len)
{ 
    char temp;
    int index = 0;
    PORTCbits.RC2 = 0; // CS active low
    while (s_len)
    {
        SSPBUF = *(ptr++);
        while (!SSPSTATbits.BF);
        temp = SSPBUF;  // clear BF flag
        s_len--;
    }
    while (r_len)
    {
        SSPBUF = 0x00;
        while (!SSPSTATbits.BF);
        rec_data[index++] = SSPBUF;
        r_len--;
    }
    rec_data[index] = ’\0’;
    PORTCbits.RC2 = 1; // end of transmission
}

void Run_Record(int num_sec)
{
    unsigned char local_num;
    PORTD = num_sec;
    local_num = PORTD;
    //while(1);

    // clear memory
    Data_To_M25P80(send_WE); // enable memory writes
    do
    {
        StrData_To_From_M25P80(&read_status, 1, 1);
    } while (rec_data[0] & 0x01);
    Data_To_M25P80(send_CE); // chip erase
    do
    {
        StrData_To_From_M25P80(&read_status, 1, 1);
    } while (rec_data[0] & 0x01);

    // initialize
    Record_Seconds = 0;
    Record_count = 0;
    Add_Start = 0x00000A;

    // configure ADC
    ADCON0 = 0x01; // activate ADC module with channel AD0
    ADCON1 = 0x0E; // allow ADC on PORTA pin 0, Vref+ = Vdd, Vref- = Vss
    ADCON2 = 0x26; // Tad = 2us, 8*Tad acquisition time, left justified

    // configure timer 0
    T0CON = 0x08; // 1:1 prescale, 16-bit timer (8 MHz rate)
    TMR0H = 0xFC;
    TMR0L = 0x18; // overflow in 125us (8 kHz sampling)
    RCON = 0x00; // disable priority levels
INTCON = 0x80; // enable interrupts, zero flags
T0CONbits.TMR0ON = 1; // enable timer
INTCONbits.TMR0IE = 1; // TMR0 interrupt
SerialROMStringSend_wLFCR(msg_recording);

while (Record_Seconds != local_num)
    PORTD = local_num;

// disable timer 0 interrupt, ADC module and timer 0
INTCONbits.TMR0IE = 0;
ADCON0 = 0x00;
T0CON = 0x00;

Add_Start -= 2;
send_PP[0] = 0x02;
send_PP[1] = 0x00;
send_PP[2] = 0x00;
send_PP[3] = 0x00;
send_PP[4] = (Add_Start >> 16) & 0xff;
send_PP[5] = (Add_Start >> 8) & 0xff;
send_PP[6] = Add_Start & 0xff;
send_PP[7] = 0x00;

do
    {
        StrData_To_From_M25P80(&read_status, 1, 1);
    } while (rec_data[0] & 0x01);
Data_To_M25P80(send_WE); // enable memory writes
do
    {
        StrData_To_From_M25P80(&read_status, 1, 1);
    } while (rec_data[0] & 0x01);
StrData_To_M25P80(&send_PP[0], 8); // fill four bytes with last address of record

void Run_Playback(unsigned long S_A, unsigned long N_Sec)
{
    unsigned char S_S, S_E, count2=0;
    unsigned long count1=4, last_address;

    // configure PWM (RC1)
    TRISC &= 0xFD; // PORTC pin 1 configured as output
    T0CON = 0x08; // 1:1 prescale, 16-bit timer (8 MHz rate)
    last_address = 4 + (N_Sec * 8000);

    // read samples from memory
    for (; count1 < last_address; count1++)
        {
                read_data[1] = (count1 >> 16) & 0xff;
        read_data[2] = (count1 >> 8) & 0xff;
        read_data[3] = count1 & 0xff;
            do
            {
                StrData_To_From_M25P80(&read_status, 1, 1);
            } while (rec_data[0] & 0x01);
}
StrData_To_From_M25P80(&read_data[0], 4, 2); // read 1 byte
//CCPR2L = rec_data[0];

TMR0H = 0x00;
TMR0L = 0x00; // initialize
T0CONbits.TMR0ON = 1; // enable timer
for (count2=0; count2 < 4; count2++)
{
    TMR0H = 0xFF;
    TMR0L = 255 - rec_data[0];
    INTCONbits.TMR0IF = 0;
    PORTCbits.RC1 = 1;
    while (!INTCONbits.TMR0IF);
    TMR0H = 0xFF;
    TMR0L = rec_data[0];
    INTCONbits.TMR0IF = 0;
    PORTCbits.RC1 = 0;
    while (!INTCONbits.TMR0IF);
}
T0CONbits.TMR0ON = 0;

}

void Run_Display(unsigned long S_A, unsigned long N_A)
{
    unsigned char count1, count2;
    if (N_A % 10)
        N_A -= (N_A % 10);
    for (; N_A > 0; N_A -= 10, S_A += 10)
    {
        read_data[1] = (S_A / 65536) & 0xff;
        read_data[2] = (S_A / 255) & 0xff;
        read_data[3] = S_A & 0xff;
        StrData_To_From_M25P80(&read_data[0], 4, 10); // read 10 bytes
        for (count2 = 0; count2 < 10; count2++)
        {
            SerialStringSend(itoa((int) rec_data[count2], &TEMP_info[0]));
            SerialCharSend( " ");
        }
        SerialCharSend(LF);
        SerialCharSend(CR);
    }
}

void Run_Delete(unsigned long S_A, unsigned long N_A)
{
    unsigned long count1, count2;
    Data_To_M25P80(send_WE); // enable memory writes
    do
    {
        StrData_To_From_M25P80(&read_status, 1, 1);
    } while (rec_data[0] & 0x01);
    if (N_A == 32)
    {
        Data_To_M25P80(send_CE); // chip erase
        do
        {
        }
{ StrData_To_From_M25P80(&read_status, 1, 1); } while (rec_data[0] & 0x01);
send_PP[0] = 0x02;
send_PP[1] = 0x00;
send_PP[2] = 0x00;
send_PP[3] = 0x00;
Data_To_M25P80(send_WE); // enable memory writes
RepeatedChar_To_M25P80(&send_PP[0], 4, 0x00, 4); // fill first four bytes with 0x00

(100%)
}

else
{
for (; N_A > 0; N_A--)
{
    send_PP[0] = 0xd8; // sector erase
    send_PP[1] = S_A & 0xff;
    send_PP[2] = 0x00;
    send_PP[3] = 0x00;
    StrData_To_M25P80(&send_PP[0], 4); // fill 64k bytes with 0xff (erase)
    S_A++;
    do
    {
        StrData_To_From_M25P80(&read_status, 1, 1);
    } while (rec_data[0] & 0x01);
}
}

void Run_Stats(void)
{
long last_address;
read_data[1] = 0x00;
read_data[2] = 0x00;
read_data[3] = 0x00;
StrData_To_From_M25P80(&read_data[0], 4, 3); // read the last data byte address written
last_address = ((long) rec_data[0] * 65536) + ((long) rec_data[1] * 256) + ((long) rec_data[2]);
if (last_address > 0x1fffff)
    last_address = 0x1fffff;
SerialROMStringSend(AW);
SerialStringSend_wLFCR(ltoa(last_address,&TEMP_info[0]));
SerialROMStringSend(PR);
SerialStringSend(ltoa((long) (100-((float) last_address/0x1fffff*100)),&TEMP_info[0]));
SerialCharSend("%";
SerialCharSend(LF);
SerialCharSend(CR);
}

#pragma code high_vector = 0x08
void interrupt_high(void)
{
  _asm
  GOTO high_isr
  _endasm

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#pragma code // resume general code functions
#pragma interrupt high_isr
void high_isr(void)
{
    if (INTCONbits.TMR0IF)
    {
        TMR0H = 0xFC;
        TMR0L = 0x18;
        INTCONbits.TMR0IF = 0; // clear flag
        ADCON0bits.GO = 1; // start AD conversion
        Record_count++; // increment msec counter
        if (Record_count == 10000)
        {
            Record_count = 0;
            Record_Seconds++;
            PORTD = Record_Seconds;
        }
        send_PP[0] = 0x02;
        send_PP[1] = (Add_Start >> 16) & 0xff;
        send_PP[2] = (Add_Start >> 8) & 0xff;
        send_PP[3] = Add_Start & 0xff;
        while (ADCON0bits.GO); // wait until conversion is complete
        if (Record_count % 2)
            send_PP[4] = ADRESH;
        else
        {
            send_PP[5] = ADRESH;
            do
            {
                StrData_To_From_M25P80(&read_status, 1, 1);
            } while (rec_data[0] & 0x01);
            Data_To_M25P80(send_WE); // enable memory writes
            StrData_To_M25P80(&send_PP[0], 6); // fill two bytes with ADC results
            Add_Start += 2;
        }
    }
}
void main(void)
{
    unsigned int count1, count2;
    TRISB |= 0x01;
    TRISD = 0x00;
    TRISA |= 0x01; // ADC input on PORTA pin 0
    // Test the LCD interface
    ADCON1 = 0x0E; // configure PortA pins for digital
    openLCD();
    cmd2LCD(0x80); // set cursor to column 1 row 1
    putromS2LCD(msg1);
    TRISC &= 0xD7; // configure SPI pins
    TRISC |= 0x10;
    SSPCON1 = 0x20; // 8MHz comm. rate
SSPSTAT = 0x40;  // CKE, CKP = 1,0

TRISC &= 0xFB;  // PORTC pin 2 output (active low chip select)

PORTCbits.RC2 = 0;
PORTCbits.RC2 = 1;  // sequence to reset the interface

StrData_To_From_M25P80(&read_ID[0], 4, 2);  // read Manufacturer and Device ID
//StrData_To_From_M25P80(&read_ID2[0], 1, 3);  // read Manufacturer and Device ID

for (count1 = 0; count1 < 2; count1++)
{
    itoa((int) rec_data[count1],&TEMP_info[0]);
    putramS2LCD(&TEMP_info[0]);
    putc2LCD(' ');
}

SerialConfig(0x24, 103);
for (count1 = 0; count1 < 30; count1++)
{
    SerialCharSend(LF);
    SerialCharSend(CR);
}

StrData_To_M25P80(&send_WS[0], 2);  // command to write status register to allow global access
Data_To_M25P80(send_WE);  // enable memory writes
StrData_To_From_M25P80(&read_status, 1, 1);
PORTD = rec_data[0];

do
{
    StrData_To_From_M25P80(&read_status, 1, 1);
    PORTD = rec_data[0];
    SerialROMStringSend(EC);
    S_Rec = RCREG;  // clear receive buffer so LFs do not accumulate
    SerialStrReceive(&TEMP_info[0]);
    S_Rec = TEMP_info[0];
    if (S_Rec == '1')
    {
        SerialROMStringSend(NS);
        SerialStrReceive(&TEMP_info[0]);
        Run_Record(atoi(&TEMP_info[0]));
    } else if (S_Rec == '2')
{  
  SerialROMStringSend(SA);
  SerialStrReceive(&TEMP_info[0]);
  Add_Start = num_to_long(&TEMP_info[0], 16);  // hex conversion
  SerialROMStringSend(NS);
  SerialStrReceive(&TEMP_info[0]);
  Num_Addresses = num_to_long(&TEMP_info[0], 10);  // decimal conversion
  Run_Playback(Add_Start, Num_Addresses);
}
else if (S_Rec == '3')
{
  SerialROMStringSend(SA);
  SerialStrReceive(&TEMP_info[0]);
  Add_Start = num_to_long(&TEMP_info[0], 16);  // hex conversion
  SerialROMStringSend(NA);
  SerialStrReceive(&TEMP_info[0]);
  Num_Addresses = num_to_long(&TEMP_info[0], 10);  // decimal conversion
  Run_Display(Add_Start, Num_Addresses);
}
else if (S_Rec == '4')
{
  SerialROMStringSend(SS);
  SerialStrReceive(&TEMP_info[0]);
  Add_Start = num_to_long(&TEMP_info[0], 16);  // hex conversion
  SerialROMStringSend(NSectors);
  SerialStrReceive(&TEMP_info[0]);
  Num_Addresses = num_to_long(&TEMP_info[0], 10);  // decimal conversion
  Run_Delete(Add_Start, Num_Addresses);
}
else if (S_Rec == '5')
  Run_Stats();
} while (S_Rec != '0');

while (1);

send_PP[0] = 0x02;  // page program command
send_PP[1] = PP_A1;  // data address (MSByte)
send_PP[2] = PP_A2;
send_PP[3] = PP_A3;  // LSBYTE
  //for (count1=0; count1 < 10; count1++)
  //  send_PP[4+count1] = send_data[count1];
  //StrData_To_M25P80(&send_PP[0], 14);  // send data to the memory locations
for (count2=0; count2 < 8192; count2++)
{
  send_PP[1] = (unsigned char) (count2 >> 8);
  send_PP[2] = (unsigned char) (count2 & 0x00FF);
  send_PP[3] = 0x00;
  RepeatedChar_To_M25P80(&send_PP[0], 4, 0x55, 256);
  cmd2LCD(0xC0);
  putromS2LCD(blank);
  cmd2LCD(0xC0);
  putromS2LCD(msg_page);
  itoa((int) count2,&TEMP_info[0]);
putsS2LCD(&TEMP_info[0]);
putsS2LCD(msg_write);
}
cmd2LCD(0xC0);
putsS2LCD(blank);
cmd2LCD(0xC0);
putsS2LCD(msg_complete);
while(1);
}
A Comprehensive and Culminating Thermodynamics Lab Competition

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Introduction

Lab components to engineering courses are valuable for providing students with hands-on experiences, demonstrating principles learned during lecture and developing basic experimental and measurement skills. Depending on the target learning outcomes, students in a lab class may take part in a variety of experiences including demonstrations, “cookbook” type experiments, guided inquiry exercises, and independent/design projects (Edwards & Recktenwald, 2010; Prince & Felder, 2006; Prince & Felder 2007). Typically the lab component runs concurrently with lectures throughout the semester, allowing the lab material to coincide with lecture material. As the semester nears completion student anxiety typically increases and it is common for instructors to spend the final lecture reviewing material rather than squeezing in one more topic. This allows students to revisit material learned, spot gaps in their knowledge, ask any lingering questions, and works to quell the building anxiety.

It was with this mentality that the following lab experience, nicknamed the Labstravaganza, was created for a standard thermodynamics course. As a way to review material learned throughout the lab component different elements from many of the individual labs were integrated into a comprehensive competition amongst student groups. The goal of this was to revisit the material without relying on lecture or testing and finish up the lab component with an academically rigorous yet spirited experience. The competition was based upon four challenges which incorporated energy and entropy balances, specific heat, the incompressible model, ideal gas laws, psychrometrics, thermocouple construction, unit conversions and required students to use their engineering judgment to make choices and predict outcomes. Surveys were used to assess student attitudes towards the exercise and possible improvements are discussed.

Competition Description

In preparation for the competition lab tables were spread out to the far corners of the room so that students would be less tempted to eaves-drop or interfere with other groups. Each table started out with all of the necessary materials that would or could be used throughout the competition. A list of these materials can be found in the Appendix. Teams of 3-4 students were created by drawing names from a hat and students were advised on the following rules:

- no cell phones, computers, or internet in any capacity
- textbook and teammates are your only reference materials
- if something is unclear ask for clarification
- any answer submitted is considered a final answer and cannot be changed
- no spying on other teams or purposely disrupting/interfering with them
- each team member must understand how conclusions were reached and be able to explain the process

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answers must be neat, easy to follow, and include units where appropriate

A lifeline was also available to the teams in the form of a single yes/no question asked of the instructor. Any clarifying questions were not considered as use of their lifeline. At the conclusion of each challenge the instructor judged the answers turned in and awarded a few extra credit points to the team who did the best. To ensure that all team members were participating, a member of the winning team was randomly selected to explain part of the team’s answer. If it was clear that the team member did not know how or why an answer was arrived at the team would forfeit the extra credit points. The different challenges were presented to the students as follows:

Unit Conversion Challenge
A common parameter in fluid mechanics is the Reynolds number which represents a ratio of inertial to viscous forces and is defined as:

\[ \text{Re} = \frac{\rho \cdot V \cdot d}{\mu} \]

In the equation \( \rho \) represents fluid density, \( V \) is fluid velocity, \( d \) is a characteristic length (i.e. diameter for pipe flows) and \( \mu \) represents the fluid viscosity. Determine the Reynolds number in the simplest units for the following air flow characteristics: (there is a 10 minute time limit for this challenge)

\[ V = 16,300 \text{ in/hr} \quad d = 8 \times 10^{-8} \text{ kJ\cdot s}^2/\text{lb\cdot cm} \quad \mu = 3.74 \times 10^{-7} \text{ lbf\cdot s/ft}^2 \quad T = 45^\circ \text{F} \quad P_{\text{gage}} = 4 \text{ Btu/ft}^3 \quad \text{(gage Pressure)} \]

Hot Can Challenge
In this challenge an aluminum can with a small amount of water in it will be placed on a hot plate. The water will be heated up to its boiling point and allowed to boil for a few moments so that steam is exiting the mouth of the can. The can will then be quickly flipped over so that the mouth is pointing towards the ground and partially submersed into a bucket of water at room temperature. Providing details and reasoning predict the outcome of this event (a P-v diagram would be good to include). There is a 10 minute time limit for this challenge.

Upon receiving all the team’s answers the process was demonstrated to the class. When a soda can with a small amount of boiling water is turned upside down and placed into cooler water there is a large decrease in pressure which causes the can to suddenly implode.

Heat Capacity and Humidity Challenge
On your table there are three different materials in a pot of boiling water: brass, aluminum and acrylic. The mass of each material is listed on a sheet on your table and their specific heats are:

\[ C_{\text{brass}} = 0.35 \text{ kJ/kg\cdot K} \]
\[ C_{\text{aluminum}} = 0.83 \text{ kJ/kg\cdot K} \]
\[ C_{\text{acrylic}} = 0.48 \text{ kJ/kg\cdot K} \]
Also on your table is an insulated vessel with 500 mL of water inside and temperature and humidity sensors. Your goal is to add one of the different materials into the vessel with the goal of maximizing the dew point temperature inside. Providing details and reasoning, predict the final dew point temperature. After turning in your prediction place the hot material into the water, wait a couple minutes while swirling the water around then determine the actual dew point temperature. There is a 25 minute time limit for this challenge.

Entropy Challenge
On your table you will find a pressurized vessel with a valve on it and an unpressurized vessel (Volume = 26.65 in$^3$) fitted with a thermocouple and flare fitting. Your goal in this lab is to maximize the total entropy within both vessels while bringing them into equilibrium. The vessels cannot be moved from their space, get wet, or have a heat source applied to them. Calculate the final entropy and the change in entropy for the system and provide your calculations and results to the instructor. Also provide the details and reasoning behind your method. There is a 50 minute time limit for this challenge.

Results
Following the competition a survey was administered to get feedback from the students on this experience. The first part of the survey had students rate certain aspects of the experience on a Likert scale and the results of this are shown in Table 1. It is seen that students responded very positively to the exercise and its use as a last day lab experience.

<table>
<thead>
<tr>
<th>Statement rated from 1-5 (1=strongly disagree, 5= strongly agree)</th>
<th>average</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Labstravaganza helped to strengthen my understanding of material presented in this course.</td>
<td>3.7</td>
</tr>
<tr>
<td>The Labstravaganza is useful as a cumulative review of material.</td>
<td>4.1</td>
</tr>
<tr>
<td>I was challenged at the appropriate level by this exercise.</td>
<td>4.2</td>
</tr>
<tr>
<td>Working as part of a team of students enhanced my learning.</td>
<td>4.3</td>
</tr>
<tr>
<td>Working as part of a team enhanced my enjoyment.</td>
<td>4.4</td>
</tr>
<tr>
<td>The Labstravaganza is a good way to wrap up the lab.</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Table 1. Labstravaganza survey results

When asked what they liked most about this exercise the students enjoyed: fun, friendly, while competitive, tied everything together and covered lots of material, working in teams, the open-ended nature, extra credit and applying what they learned. When asked how this exercise could be improved the students commented that they would have liked more time or less problems, more lifeline questions for the instructor, more extra credit plus food and more explosions.

Due to the overall positive response from the students it seems that using a competition such as this is a great way to wrap up the lab component of a course. In the future more time should be allowed for the challenges, perhaps an extra 30% than suggested above, while incorporating less problems. In fact only the Hot Can Challenge had all teams submit an answer within the allotted time. With some creative thinking it may be possible to cover as many topics with fewer challenges. Alternatively, an instructor could review how the class performed on different labs earlier in the semester and use this as guidance in coming up with challenges that would incorporate only material that was initially struggled with. Incorporating the student suggestion of allowing more questions of the instructor could also work in reducing the time required to
complete any challenge, though this must be balanced with a desire to force the students to figure things out as a team.

Finally, on the Entropy Challenge students seemed to not think very creatively. Despite understanding causes of entropy generation such as friction, heat transfer, and sudden processes they did little to incorporate these thoughts into how they connected the different vessels. It was common to see the groups cut a short piece of copper tubing and add flare fittings to attach the vessels and then simply open the valve. Each table had 25 feet of copper tubing at their disposal plus a propane torch allowing much greater increases of entropy to be generated as the vessels were brought into equilibrium. In the future students should be prodded and encouraged to think critically about causes of entropy generation and creatively on how to incorporate them via the materials they have at their disposal for this challenge.

References


Appendix

Materials provided to the students included:

- boiling water with samples of brass, aluminum and acrylic
- thermocouple wire
- wire stripper
- thermocouple connector
- small screwdriver
- thermocouple reader
- relative humidity sensor
- insulated 64 oz. plastic mug with lid
- 26.65 in³ pressurized air cylinder (50 psi) fitted with ball valve
- empty 26.65 in³ air cylinder fitted with thermocouple and flared fitting inlet
- 25 ft. of copper tubing (1/4 in. ID)
- tools for making flared tubing connection
  - 45° flaring block
  - tube cutter
  - ¼ in. swaging punch
  - hammer
  - flare nuts
- tools for soldering
  - propane canister and torch tip
  - flame striker
  - flux and flux brush
  - emery cloth
  - heat proof pad
  - vise
  - pliers
- eye protection
**Intelligent Control on the S12 Microcontroller**

**Using Fuzzy Logic Instructions**

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**Introduction**

Intelligent Control is a modern phrase that implies using creative algorithms in computer control applications to address problems in unusual, or “intelligent,” ways. One tool that is used to implement Intelligent Control is Fuzzy Logic, a scheme by which computer applications can make decisions on imprecise, incomplete, or “fuzzy” information. This approach to Intelligent Control has seen application in various commercial products, from home appliances to sophisticated system designs. The value of using Fuzzy Logic in such applications depends on the situation. Using Fuzzy Logic to detect and control the “darkness” of a piece of toast in a toaster seems to be a force-fit application, but in more complex situations, Fuzzy Logic allows implementation of non-linear control without complicated mathematical support.

The Freescale S12 microcontroller includes specific instructions in its instruction set to support Fuzzy Logic applications. The presence of these four instructions as primitive operations in the S12 makes that microcontroller unique, and especially well-suited to Intelligent Control applications. This paper details those instructions in the S12’s instruction set that implement Fuzzy Logic operations, and provides some applications in which the S12’s Fuzzy Logic capabilities are used.

During Spring semester, 2010, a Design Workshop course was offered in which students used the S12 microcontroller to implement applications of Intelligent Control. Based on the experience of teaching that workshop, a similar Design Workshop course is scheduled for Fall semester, 2010. This paper will include some results from the design projects conducted during the Spring workshop as examples of Intelligent Control applications using Fuzzy Logic.

The Freescale S12 processor is probably the most popular general-purpose 16-bit microcontroller currently on the market. It is used as the focus for microprocessor/microcontroller courses in many Electrical or Computer Engineering programs across the country. However, the four instructions in the instruction set that implement Fuzzy Logic primitives are often omitted from discussion because their use requires an understanding that exceeds normal microcontroller applications. This paper tries to remove the mystery surrounding the Fuzzy Logic capabilities of the S12 microcontroller, and demonstrates how they can be used for Intelligent Control.

**Overview of the Fuzzy Logic Instructions**

The S12 microcontroller includes four primitive instructions in its instruction set specifically intended to support Fuzzy Logic operations. These are MEM, REV, REVW, and WAV, and they are introduced briefly below. Following sections of this paper will discuss the instructions in more detail.
The MEM (membership) instruction performs the first step in Fuzzy Logic operations known as fuzzification of the external crisp input values. This produces a set of fuzzy input variables that are later combined to produce fuzzy output values.

The REV and REVW (rule evaluation and weighted rule evaluation) instructions perform the meat of the fuzzy calculations, using the fuzzy input variables produced by MEM and generating fuzzy output values.

The WAV (weighted average) instruction performs the final step of Fuzzy Logic operations known as defuzzification. It takes the fuzzy output variables and transforms them into crisp system outputs that can then be used in traditional processing.

These three steps, fuzzification, rule evaluation, and defuzzification, form a brief outline of any Fuzzy Logic application, and each step is implemented by a primitive instruction in the S12 microcontroller’s instruction set.

**MEM Instruction**

The MEM (membership) instruction takes crisp input values received from transducers or other devices and generates fuzzy input variables that represent the extent to which the crisp input values belong to certain fuzzy categories, or labels. The crisp input can be fully a member of a certain category, partially a member of that category, or not a member at all. To be specific, imagine a system that controls the water temperature in a shower for people of various ages.

Labels are implemented via trapezoidal membership functions, as depicted in Figure 1. This figure shows five labels for water temperature, each with an associated trapezoidal membership function, to take an input water temperature from a sensor and categorize the temperature as cold, cool, warm, hot, or scalding. It also shows a second set of trapezoidal membership functions that depict three labels, young, adult, and senior, based on the age of the shower user. In each case, the crisp input, (water temperature or age) is represented by a one-byte number in the range 0 to 255 on the horizontal axis, and the resulting fuzzy values are also represented by one-byte numbers in the range 0 to 255 on the vertical axis.

![Figure 1. Membership functions that fuzzify two crisp input values, water temperature and age, and produce eight fuzzy input values, cold, cool, warm, hot, scalding, young, adult, and senior.](image-url)
To use the MEM instruction, the trapezoidal membership functions must be described in the microcontroller. This is accomplished via a data structure that records four numbers for each trapezoid: left x-axis intercept, right x-axis intercept, left slope, and right slope (negated). Thus, the “cool” trapezoid in Figure 1 would be described with the data structure 40, 70, 25, 25 in the S12’s memory. Infinite slopes are represented by a special-case slope value of 0. The four values for each trapezoid are stored sequentially in memory.

Before executing MEM, three registers in the S12 CPU must be initialized. Register A holds the crisp value being fuzzified. Register X holds the address of the first byte of the trapezoidal function being evaluated. Register Y holds the address in memory where the resulting fuzzy input value is to be stored. MEM is executed once for each trapezoid in the set of membership functions. In this example, eight separated MEM instructions must be executed, five with register A holding the crisp water temperature, and three with register A holding the crisp age of the shower user.

The result of executing MEM for each of the trapezoids is a list in memory of fuzzy input values representing the extent to which each crisp input is a member of the associated fuzzy category identified by each trapezoid. These fuzzy input values are then used in the next step of the processing.

**REV and REVW Instructions**

The REV and REVW (rule evaluation and weighted rule evaluation) implement the meat of the Fuzzy Logic processing. Through these instructions, fuzzy inputs produced by MEM are combined using a set of rules to produce fuzzy outputs. The rules are a collection of statements that describe the fuzzy output based on characteristics of the fuzzy inputs. In the example discussed here, the single fuzzy output describes how to change the shower water temperature, given the fuzzy inputs that describe the characteristics of the current measured temperature and the age of the shower user.

Figure 2 shows a typical set of rules that might be used in this shower temperature control example. In the table, the action required to adjust the water temperature is identified for each of the possible categories of water temperature and age of the shower user. Entries in the table mean the following: ↑↑ = raise temperature quickly, ↑ = raise temperature slowly, ↔ = leave temperature unchanged, ↓ = lower temperature slowly, and ↓↓ = lower temperature quickly.

<table>
<thead>
<tr>
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<td>young</td>
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<td>adult</td>
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<td>senior</td>
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*Figure 2. Rules used by REV and REVW to generate fuzzy outputs from fuzzy inputs*
To use the REV and REVW instructions, the list of rules shown in Figure 2 must be stored in the S12 memory in another data structure. Each box in Figure 2 is represented with a list of bytes that record the statement “If the water temperature is (...) AND the showerer is (...) THEN adjust the water temperature in this way (...)” where each of the (...) represents a fuzzy input produced by MEM or a fuzzy output generated by the REV or REVW instructions. Thus, a sample rule would be “If the water temperature is cool AND the showerer is young THEN raise the temperature slowly.”

The difference between REV and REVW is that REV allocates the same “weight” to each rule, meaning that each rule has equal impact on the resulting fuzzy output. By contrast, REVW allows the programmer to assign weights to the various rules so that some rules have more impact on the fuzzy output result than others. The data structures in memory for REV and REVW differ in order to accommodate this weighting feature. In order to avoid confusion, suffice it to say that the data structure specifying the list of rules identifies, for each rule, the fuzzy inputs that are combined with the AND operator, and identifies the fuzzy output that is produced by that rule. Rules are stored consecutively in memory, and are separated by special “marker” values stored between the rules in the data structure. Results of the rules are combined with the OR operator to determine the final value of the fuzzy outputs. In this example, there are five fuzzy outputs: raise the temperature quickly, raise the temperature slowly, leave the temperature unchanged, lower the temperature slowly, and lower the temperature quickly.

Numerically, the AND operator in Fuzzy Logic is implemented as an arithmetic minimum operator, so that the AND of two fuzzy inputs is just the minimum value of the two fuzzy values. The OR operator in Fuzzy Logic is implemented as an arithmetic maximum operator, so that when rule results are combined by ORing them, the fuzzy output value is just the maximum value produced by each of the rules being combined.

The result of rule evaluation is a set of fuzzy output values indicating the extent to which each of the output actions should be taken. Thus, in this example, five numbers are produced in the range 0 to 255, one for each of the five actions that should be taken on adjusting the water temperature. This form of the result is not particularly useful for the system that actually must control the water temperature. Thus, there is one more step in the process.

**WAV Instruction**

The WAV (weighted average) instruction takes the fuzzy outputs produced by REV or REVW and combines them to produce a crisp output value that can then be used in further traditional processing. This is accomplished by assigning a set of ideal values, known as “singletons,” to each of the fuzzy outputs, and then performing a weighted average calculation using the fuzzy outputs as “weights” to condition the singleton values associated with each fuzzy output. This calculation is much the same as a “center of mass” calculation in a mechanical system. The resulting number is a value somewhere within the limits established by the specified singleton values, determined by the fuzzy outputs that specify the extent to which the output should represent each of the fuzzy output labels.
In this example, if the fuzzy outputs say that the water temperature should be raised slowly to a large degree, left unchanged to a small degree, and lowered not at all, the resulting value after WAV will be a value between the singleton values for raise slowly and leave unchanged, shaded toward the raise slowly singleton according to the weights identified in the fuzzy output variables.

**Example Applications**

Students in the Electrical and Computer Engineering Design Workshop course during Spring semester, 2010, used the S10 microcontroller and its Fuzzy Logic instructions to implement various applications of Intelligent Control. Some of these student projects are described here.

In the “Intelligent Greenhouse” project, students designed a system that controls the environment of growing plants. The system measures temperature and humidity in a greenhouse atmosphere and uses those values as crisp inputs to the system. Employing Fuzzy Logic, the system generates signals to control heat and ventilation of the greenhouse to optimize conditions for plant growth. The results of this project were hard to demonstrate, but plants did grow, so something must have been right.

In the “Color Recognition for Tracking Robots” project, students designed a typical line-following robot, but added a twist. The color of the line being tracked controlled the speed of the robot. A green line indicated full speed. A blue line slowed the robot, and a red line caused the robot to stop. Filtered sensors were used to detect the color of the line, and Fuzzy Logic was used to combine the crisp sensor outputs and to generate the control signal to specify robot speed. This project worked well, after some difficulty in properly sensing the different colors.

The “Path Tracking” project was also based on a line-following robot, but in this case the line sometimes included alternate paths which could be selected by the robot, based on the surrounding environment and the intended destination. The robot used infrared sensors to detect the line, and ultrasonic sensors to detect surrounding obstacles. By combining the line-tracking sensor information with information about surrounding obstacles, the robot was able to make intelligent decisions when faced with a bifurcation in the path it was following.

Two projects attempted to use spoken commands to control a system. One project included a multi-color light display, and the user could light one or more colors of lights by speaking the color. Colors could be brightened or darkened by speaking “more” or “less” as well. This project did not function well. The second voice-control project did better, using spoken commands to control the speed and direction of a motor. The S12 processor does not have any special support for signal processing, so these projects attempted to just capture the frequency pattern of spoken input and analyzed that pattern to determine appropriate actions.

A final project equipped a motorcycle helmet with ultrasonic sensors to detect surrounding obstacles. A “threat level” indication was provided for the helmet wearer to indicate the presence and direction of detected obstacles. Intelligent Control attempted to analyze the threat situation and report the severity of the threat via lights in the peripheral vision of the user.
Student reactions to using Fuzzy Logic to implement control systems for their projects ranged widely. Some students appreciated the opportunity to implement a control scheme using a state-of-the-art technique, and eagerly dove into their projects. Other students were not convinced that the use of Fuzzy Logic in their projects justified the added complexity in their software required to support that approach. It is true that with the level of complexity addressed here in these student projects, the full benefit available through the power of Fuzzy Logic systems is not realized. In more complicated cases, however, Fuzzy Logic can be used effectively to implement cleanly a control system that otherwise would require many levels of mathematical modeling and simulation.

Summary

Intelligent Control applications were successfully implemented by students in the Design Workshop Class during Spring semester, 2010, using the Fuzzy Logic capabilities of the S12 microcontroller. No conclusion is drawn here that Fuzzy Logic is the best, or even an appropriate vehicle for solving these problems, but the availability of Fuzzy Logic support instructions in the S12’s instruction set makes the approach at least viable. Experience with these primitive applications of intelligent control using Fuzzy Logic demonstrated the processing power that is available through special features of today’s systems. That experience may encourage instructors in microprocessor classes using the S12 processor to address the capabilities available through the Fuzzy Logic instructions in its instruction set.

References


Biography

CHRISTOPHER R. CARROLL received a Bachelor degree from Georgia Tech, and M.S. and Ph.D. degrees from Caltech. After teaching at Duke University, he is now Associate Professor and Assistant Head of Electrical and Computer Engineering at UMD, with interests in special-purpose digital systems, VLSI, and microprocessors.
A COST-EFFECTIVE ANTENNA POSITIONING SYSTEM FOR MODERN RADIO-FREQUENCY (RF) AND MICROWAVE ANTENNA MEASUREMENTS


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INTRODUCTION

Recently, the microwave test equipment in the Electrical and Computer Engineering Department (ECE) at North Dakota State University (NDSU) was significantly upgraded. A new Agilent E5071C 8.5 GHz ENA series network analyzer and an anechoic chamber were two major pieces added to the lab. This upgrade required the development of an antenna measurement system (AMS) that could be used to measure the far-field behavior (i.e., field patterns) of an antenna. To develop an AMS a team consisting of ECE seniors was assembled. This team designed an AMS system that uses LabView to interface with the Agilent network analyzer and a structure that rotates the antenna in both the E- and H-planes. The computer running LabView interfaces with the network analyzer using the Ethernet and interfaces with the rotating structure using an infrared (IR) port. By correlating the $S_{12}$ data from a network analyzer to the angle of rotation of the structure, a complete far-field pattern of the antenna can be measured. This paper will summarize the design and operation of the AMS along with the total cost. The cost of the AMS is about 10% of the cost of commercially available systems, thus making the system attractive to programs with a limited budget.

MOTIVATION FOR AN ANTENNA MEASUREMENT SYSTEM

Wireless communications is being studied extensively and has attracted the attention of many researchers throughout the world. A major component in all wireless systems is the antenna. These antennas mainly consist of three-dimensional antennas (Balanis, 2005) and planar antennas (Waterhouse, 2007). Therefore, when a novel antenna is developed, a system of testing the performance of this antenna is required. One method of testing a newly developed antenna is to use an AMS.

An AMS measures two main properties of an antenna: radiation pattern and input impedance. By measuring the radiation pattern of an antenna, a designer is able to determine the performance of the antenna in the space surrounding the antenna (this space is usually air). From this information, the direction the antenna is radiating the most power can be determined as well as how much power is actually radiated by the antenna (i.e., gain) and how much is being lost in the material used to construct the antenna. The AMS can also be used to measure the input

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impedance of the antenna. If done correctly, this measurement results in a value representing the input impedance of the isolated antenna element and does not include the influence of the antenna feeding network. This value is useful for proper design of efficient power delivery to the antenna by a transmitter or efficient power delivery by the antenna to a receiver.

TOPOLOGY OF THE ANTENNA MEASUREMENT SYSTEM

The AMS consists of three major components: 1) antenna positioner, 2) network analyzer and 3) computer. The topology of the entire system is shown in Fig. 1. The following sections describe the operation of each major component.

Antenna Positioner
The antenna positioner rotates the antenna under test 180 degrees in both the x-z and y-z planes. Photographs of the antenna positioner are shown in Fig. 2. The step size of the positioner is defined by the user on the computer using the LabView software. Two servo motors control the antenna positioner. One servo motor rotates the antenna mast from 0 to 180 degrees (illustrated in Fig. 2 by the white arrows) at defined step sizes and the second servo rotates the plate at the top of the antenna mast from 0 degrees to 90 degrees in one step. In summary, the motions of the antenna positioner during a measurement are as follows: 1) the bottom servo rotates the mast from 0 degrees to 180 degrees at step sizes defined by the user; 2) when the mast is rotated to 180 degrees, the second servo rotates the antenna plate at the top of the mast 90 degrees in one step; 3) then the servo at the bottom of the mast rotates the mast back from 180 degrees to 0 degrees at the step sizes defined by the user. It should also be noted that the user can define a specific time delay between each step taken by the servo motor. This allows the mast to settle before measurements are taken by the network analyzer.

![Fig. 1. The topology of the antenna measurement system.](image)
The network analyzer is the piece of equipment that takes the actual field measurements. This is done by attaching an antenna to port 1 and the antenna under test (AUT) to port 2 (as shown in Fig. 1), both with coaxial cables, and placing both antennas in an anechoic chamber. An image of the network analyzer and the anechoic chamber is shown in Figs. 3 and 4, respectively. The network analyzer provides measurement results in the form of the scattering matrix. These measurements determine how well the AUT is receiving power and how well the two antennas are linked in the chamber. The measurements on how well the antennas are linked provide the necessary information about the antenna as to how well the AUT is radiating into the region around itself.

Fig. 3. Agilent Technologies network analyzer.
For correct operation of the system, it is essential that the PC must manage the timing and information between the network analyzer and the antenna positioner. The PC is connected to the network analyzer through the Ethernet port and connected to the antenna positioner through an infrared (IR) port. An image of the IR port and controlling circuitry is shown in Figs. 5 – 7 (schematics for these boards are shown in the Appendix). The PC controls the system with a single user interface written in LabView. A screen-shot of the LabView interface is shown in Fig. 8.

**Computer**

**Fig. 4.** Anechoic chamber.

**Fig. 5.** IR boards used to communicate between the PC and the antenna positioner.

**Fig. 6.** PC board used to send data from the PC to the antenna positioner to control the servos.
Fig. 7. PC board used on the antenna positioner to receive data from the PC to control the servos.

Fig. 8. LabView Interface.
DESCRIPTION OF THE ANTENNA MEASUREMENT SYSTEM

When a measurement is underway, the following sequence of events occurs:

1) When the system is setup and initialized (i.e., angle = 0 degrees), the PC records the first values from the network analyzer.
2) When this value is recorded the PC communicates with the antenna positioner and rotates the mast from 0 degrees to $0 + \Delta$ degrees where $\Delta$ is the user-defined angle step size in LabView.
3) After a short wait time, the new value measured by the network analyzer is recorded by the PC and stored in a manner related to the angle of the mast (i.e., each measurement corresponds to an angle of the antenna positioner).
4) After this value is recorded by the PC, the PC rotates the antenna positioner to $0 + 2\Delta$ degrees.
5) The PC then waits a short time and records the new measurement in the same manner as in step 3).
6) Steps 4) and 5) are repeated until the antenna positioner reaches a mast angle of 180 degrees. At that point the antenna plate rotates 90 degrees and the measurement process is repeated from 180 degrees back down to 0 degrees.
7) The result from this measurement is a matrix that contains measurement values from the network analyzer and corresponding antenna positioner angles.
8) LabView draws a polar plot of the measurement values and corresponding angles.

COST

The AMS system developed at NDSU has shown to be a reliable and accurate system. The budget for the entire project was $750. This low cost places the AMS system in reach of many smaller ECE programs.

CONCLUSION

A simple cost-effective antenna measurement system has been presented. The topology of the system has been summarized and details of the three main components have been summarized. Furthermore, a detailed sequence of events involved with a typical measurement has been offered. This was then followed by a total cost summary of $750 which makes this system affordable for many smaller ECE programs.

REFERENCES


BIOGRAPHICAL INFORMATION

JOSHUA T. ANDERSON is an undergraduate student at NDSU. He is currently employed at PacketDigital, LLC in Fargo, ND as a cooperative education student. He will graduate with his B.S. degree in Electrical Engineering at NDSU in December 2010.

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DAVID A. ROGERS is a Professor of Electrical and Computer Engineering at NDSU. He earned the B.S.E.E. and Ph.D. (E.E.) degrees from the University of Washington, the M.S.E.E. from Illinois Institute of Technology, and the M. Div. (Ministry) degree from Trinity Evangelical Divinity School.

APPENDIX

![Transmitter schematic](image)

Fig. 9. Transmitter schematic.
Fig. 9 is an image of the Transmitter schematic. This circuit contains the following components:

- (2) LED indicators
- (7) 4.77µF capacitors
- (4) 1kΩ resistors
- (2) push button
- (1) MC33063A voltage regulator
- (1) MCP2120 IrDA driver
- (1) 10kΩ TrimPot
- (1) 100kΩ TrimPot
- (1) PIC18F242-I
- (2) 40MHz Crystals

This circuit contains a PIC that sends data to a MCP2120, which is the IrDA encoder/decoder. The MCP2120 then sends the data to the IrDA transceiver. There is a 1x4 header that connects to a 4 conductor ribbon cable from the IrDA PCB. There is also a 2x8 header that connects to a 16 conductor ribbon that runs to a backlit LCD screen. The various capacitors and resistors are used to reduce noise throughout the circuit. The two push buttons are to reset various devices.

Fig. 10. Receiver schematic.

Fig. 10 is an image of the schematic for the Receiver PCB. This circuit contains:

- (2) LED indicators
- (14) 4.77µF capacitors
- (4) 1kΩ resistors
- (2) 10kΩ resistors
- (1) 100kΩ resistor
- (1) MC33063A voltage regulator
- (1) MCP2120 IrDA driver
- (1) 10kΩ TrimPot
- (1) 100kΩ TrimPot
- (1) Pololu Micro-Controler SSC03A
- (1) MAX232A RS-232 driver
- (1) PIC18F242-I
- (2) 32.768kHz Crystals
This circuit contains a PIC that sends data to a MCP2120, which is the IrDA encoder/decoder. The MCP2120 then sends the data to the IrDA transceiver. There is a 1x4 header that connects to a 4 conductor ribbon cable from the IrDA PCB. There is also a 2x8 header that connects to a 16 conductor ribbon that runs to a backlit LCD screen. The various capacitors and resistors are to reduce noise throughout the circuit. The MAX232 is used to convert from UART to RS232 for the Pololu Micro-Controller. The four push buttons are used to reset various devices, and the MC33080 is for power regulation.

![IR board schematic](image)

Fig. 11. IR board schematic.

Fig. 11 is an image of the schematic for the IR circuit. This board contains the following components:

- (2) 1kΩ resistors
- (2) 4.7µF capacitors
- (2) TFDU4101 Vishay Infrared Transceivers
- (1) 4 pin header to connect to transmitter or receiver

This circuit connects two IrDA transceivers in parallel to increase our transmission range. The 1x4 header connects by a 4 conductor ribbon cable to either the transmitter or receiver. The resistors and capacitors in the circuit are there to reduce noise throughout the circuit.
Addressing Intellectual Property (IP) and Student Needs in Industry Collaborative Student Projects

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Abstract: Many engineering programs are encouraging collaborative student projects with industry sponsors. These joint or sponsored projects can benefit both students and sponsors providing real world experience for the students and low cost research or development opportunities for the sponsor. However, both sides must enter into these arrangements with open eyes and realistic expectations. This paper will explore the balance of interests among (i) students’ career advancement, (ii) non-disclosure obligations, (iii) intellectual property (IP) rights, and (iv) project funding.

Introduction: The Electrical and Computer Engineering and Technology department at Minnesota State University, Mankato has approximately 25 electrical and computer engineering students graduate each year. The department is fortunate to be supported by a very active Industrial Advisory Board (IAB). This board meets at least twice a year and has in the past been involved in reviewing student senior design projects. As a result of IAB member interest and involvement with local industry and inventors, the Fall 2009 and Spring 2010 senior design experiences were truly collaborative and real world experiences. The first project consisted of a rework of an existing commercially available product. The second design effort consisted of taking a concept that was undergoing patent protection and creating hardware to support demonstration of the proof of concept. Both experiences were incredibly positive for the students and sponsors but also provided challenges that others following this path should be aware of.

Design experience 1. The Fall 2009 senior design experience truly began during the summer of 2009 with the course instructor meeting with the president of the company with the product needing redesign. The product is a very successful commercial product in which the company is planning to move from a dated input method into something that is more user-friendly. Further, the project was to explore the possibility of adding additional data storage and analysis to provide the company with a recurring income stream. The project provided many lessons learned for course instructor, the project sponsor and also the students. These will be described in general terms because currently the project is still under a nondisclosure agreement.

Positives associated with this project:
- Students were able to visit the production location.
- Students were able to see current products and move a current product into the lab for redesign.
- Students were able to use the current product as a test-bed.
- Students had to work with existing portions of current product which forced them to work
with real-world constraints

Design Experience 1 Implementation: The students were divided into teams of three or four. Each team was assigned a portion of the project and in some cases teams had overlapping or parallel responsibilities. One of the challenges associated with this is that some teams had more of a hardware focus while others had more of a software focus. Efforts in senior design are always expended to make sure students have a balanced hardware and software experience as part of their final design experience. Because this design needed to be completed in one semester students chose to use many off-the-shelf components and became in many cases systems integrators.

Challenges that occurred with this project:
- The students have a limited ability to discuss the project with others because of nondisclosure agreements required by industry sponsor.
- Time dependency created significant challenges in a one credit class to complete this effort within 15 weeks.
- The end result really has become a proof of concept rather than something that can be easily manufactured.
- Students because of the very rapid need to get this done in many cases did not have as holistic experience as with other projects.
- Dependencies of one group on the deliverable of another group became a challenge. Timeline slipping for one group and their deliverables created significant of issues with others resulting in finger pointing.
- How does the sponsoring company move forward with lessons learned?

Design experience 2: The second design experience occurred as a result of the discussion with one of our IAB board members who was working with a firefighter seeking a patent for his invention. As a starting point the firefighter came and presented his system concept to the senior design course during the second class meeting in the Spring 2010 semester. During the remainder of the week the students in the class were required to submit brief project proposals of what they would like to do for their final semester project in the senior design course to the course instructor. Based on the information provided by our potential sponsor two groups decided to undertake designs to support his product development. In both cases these teams had three members and in both cases the teams elected to take portions of the project that covered both hardware and software concepts. The nondisclosure agreement (NDA) was prepared and provided students for their examination and acceptance. Students who elected to work on this project had to complete and abide by the nondisclosure agreement. This agreement was iterated upon multiple times to make sure that students had the ability to discuss the project with potential employers and yet the provisions of the agreement would protect the inventor from inappropriate disclosures. Key provision of a sample agreement can be found at the end of this paper.

Students working on this project provided regular updates to the project sponsor showing both successes and challenges. Expenses for this project unlike those for other senior design projects were covered by the inventor. The course instructor however discussed with students the need to be charging only for successes and not imposing the cost of learning on the inventor. Students
commenting on the differences in the both real world experiences pointed at the advantages of looking at a project in which they as a team were responsible for all aspects rather than depending upon other teams to meet other design requirements.

**Issues to be resolved before design efforts start:**

- All involved must have a clear understanding of the NDA and what it requires and what limitations it imposes. It is recommended that as we did, the author be available to discuss the implications of the NDA with students.
- It is critical when efforts like this occur in a one semester course that groundwork for this occur before the semester starts.
- The scope of each team’s assignment and the required design interfaces between teams should be carefully matched to team size so that each team can produce a useful prototype independent of the progress of other teams.

**Concluding thoughts:**

The current course configuration for senior design at Minnesota State University Mankato provides students one course credit for each semester of effort in their senior design course. Most students are completing 15 credits of coursework during both semesters in their senior year. Additionally, most students are working part time to fund their education and in the Spring semester most students further increase their workload by seeking fulltime employment.

The positives associated with industry sponsorship are great! Comments from students working on the projects point to the positive experience of working on a project that really can make a difference. The students realized that their efforts supported increasing corporate viability of a small company with their first semester effort and developed the prototype for a new system in the second system effort that could be the basis or helping or protecting others. The students’ efforts were further validated when the prototype from the second semester effort won the grand prize award at the 2010 Minnesota Inventors Congress.

Questions that still exist: What happens at the end of the semester – what should really happen? Students want/need to move on but small companies still need help moving forward. In the case of the second design system the Inventors Congress provided public exposure and opportunities for this inventor to continue moving forward. In the case of the other system the course instructor is still working with the company trying to find cost-effective engineering talent to move their product line forward.

**Lessons learned:**

- As has been found in the past, student teams of greater than three reduced the learning experience and were much harder to coordinate and grade.
- Student teams that depend upon others result in significant finger-pointing.
- Faculty engagement with industry sponsored projects significantly increases the faculty workload.
- Students engage and expend significantly more effort on projects with external sponsorship.
- Industry expectations must be clearly managed with it being clearly understood that the output of student projects is best viewed as proof of concept.
• Students in a senior design course are not well-equipped to create true manufacturing prototypes.
• Students need to have an understanding of intellectual property and appropriate documentation before entering into industry sponsored projects.
• Students’ willingness to complete documentation with industry sponsored projects is better than with faculty directed and created projects.
Appendix A

Selected Provisions of a Nondisclosure Agreement suitable for industry-student collaboration effort

These provisions are between students or faculty members (“PARTICIPANT”) in an identified course during a specified semester and the industry sponsor (“SPONSOR”). The key provisions addresses issues relating to (1) proprietary information, (2) ownership of inventions, and (3) non-competition.

1. Proprietary Information

   a. Restrictions on Proprietary Information

   I agree that, during the COURSE and after, I will hold the Proprietary Information of the SPONSOR in strict confidence and will neither use the information nor disclose it to anyone, except to the extent necessary to carry out my responsibilities as a PARTICIPANT of the COURSE or as specifically authorized in writing by the SPONSOR.

   I understand that "Proprietary Information" means all information pertaining in any manner to the business of the SPONSOR or its affiliates, consultants, or business associates, unless:

   i. the information is or becomes publicly known through lawful means;
   ii. the information was part of my general knowledge prior to the COURSE; or
   iii. the information is disclosed to me without restriction by a third party who rightfully possesses the information and did not learn of it from the SPONSOR.

   This definition includes, but is not limited to, (A) schematics, techniques, development tools, processes, computer printouts, computer programs, design drawings and manuals, electronic codes, formulas and improvements; (B) information about costs, profits, markets, sales, customers, and bids; and (C) plans for business, marketing, future development and new product concepts.

   b. Permitted Disclosures

   SPONSOR authorizes limited disclosures of certain Proprietary Information as follows:

   i. For the purposes of a job interview for employment, PARTICIPANT may discuss technical information about the sub-system to which PARTICIPANT was primarily assigned, and its input signals and output signals, only to the extent it does not suggest or reveal the overall operation of the system as a whole; PARTICIPANT may not discuss or mention any information about the other sub-systems to which the PARTICIPANT was not primarily assigned.

   ii. In the event that PARTICIPANT desires to disclose more than permitted in clause 1(b)(i), PARTICIPANT may request permission from SPONSOR in writing (including by e-mail) at least 10 business days before any disclosure to permit SPONSOR a reasonable opportunity to file a patent application to preserve SPONSOR's rights to seek foreign patent protection. The written request must fully describe, in text, and/or drawings, the entire subject matter that PARTICIPANT seeks permission to disclose. SPONSOR will not unreasonably deny permission to disclose limited amounts of technical information, but permission may not be granted for disclosure of marketing or end-use application information. Where possible, SPONSOR may grant written permission to PARTICIPANT in less than 10 business days upon request.

2. Inventions

   a. Assignment of Inventions

   Proceedings of the 2010 ASEE North Midwest Sectional Conference
At or before the end of the COURSE, I agree to assign to the SPONSOR, without further consideration, my entire right, title, and interest (throughout the United States and in all foreign countries), free and clear of all liens and encumbrances, in and to all Inventions. Notwithstanding the foregoing, the SPONSOR may, in its discretion, agree to provide consideration for certain Inventions through a written agreement between the SPONSOR and the undersigned which specifically provides for such consideration; in all other cases, no consideration shall be paid. The Inventions shall be the sole property of the SPONSOR, whether or not copyrightable or patentable. In addition, I agree to maintain adequate and current written records on the development of all Inventions, which shall also remain the sole property of the SPONSOR. I understand that "Inventions" means all ideas, processes, inventions, technology, designs, formulas, discoveries, patents, copyrights, and trademarks, and all improvements, rights, and claims related to the foregoing, that are conceived, developed, or reduced to practice by me alone or with others during and for the COURSE. The foregoing shall not apply to an invention that the PARTICIPANT developed entirely on his or her own time without using the SPONSOR's equipment, supplies, facilities, or trade secret information.

3. Non-Compete

PARTICIPANT agrees not to engage in any activity that is competitive with any activity of SPONSOR during the course of their relationship and for a period of 12 months after termination of the Agreement. For purposes of this paragraph, competitive activity encompasses forming or making plans to form a business entity that a reasonable person participating in the COURSE would believe may be deemed to be competitive with any business of SPONSOR. This does not prevent PARTICIPANT from seeking or obtaining employment or other forms of business relationships with a competitor after termination of the COURSE so long as such competitor was in existence prior to the termination of the COURSE and PARTICIPANT was in no way involved with the organization or formation of such competitor.

Biographies

William B. Hudson  Dr. Hudson has been teaching senior design at Minnesota State University for 8 years. Prior to joining the faculty at Minnesota State Dr. Hudson held faculty positions at Kansas State University and New Mexico State University and industry positions at Lindsay Manufacturing, Sprint as well as serving as a consultant.

Craige O. Thompson, JD, EE, PE.  Mr. Thompson directs Thompson Patent Law Offices PC, a patent boutique law firm that provides experienced counsel on offensive and defensive patent matters. Previously, Mr. Thompson practiced law at Fish & Richardson for 7 years, after a 10 year career as a design engineer with Plexus Corp.
INTRODUCTION

The University of Minnesota Duluth offers Bachelor of Science degrees in Chemical, Civil, Electrical and Computer, Industrial, and Mechanical Engineering with a combined enrollment approaching 1000 students. In addition, Master of Science degrees in Electrical and Computer Engineering, Engineering Management, and a Master of Environmental Health and Safety program are also offered. To respond to our constituencies, the increasing regional need for professional development opportunities for engineer practitioners, and recognizing that there are potential changes in obtaining licensure requirements, UMD now offers a Professional Master of Engineering degree. The Professional Master Of Engineering degree emphasizes the practice of engineering in either the private or public sector. This new degree program, approved at the December 2009 Board of Regents Meeting, focuses on developing competencies in the areas of engineering design, problem solving, and practice beyond what can be achieved in earning a Bachelor of Science degree in a given engineering discipline.

An MEng graduate student is expected to have a focus and degree designation in one of the core UMD disciplines of Chemical Engineering, Civil Engineering, Electrical and Computer Engineering, Industrial Engineering, or Mechanical Engineering.

This paper provides some background in the development and implementation of this degree program and its expected impact on regional engineering education.

JUSTIFICATION

We are basically responding to a key portion of the UMD Mission Statement which reads, “UMD serves northern Minnesota, the state, and the nation as a medium-sized comprehensive university dedicated to excellence in all of its programs and operations. As a university community in which knowledge is sought as well as taught, its faculty recognizes the importance of scholarship and service, the intrinsic value of research, and the significance of a primary commitment to quality instruction…….” Our constituencies in the region also includes the Iron Range public and private sector employers. Our engineering graduates, public and private sector employers, and the professional societies have asked for expanded graduate engineering professional development opportunities.
A flexible, primarily coursework, MEng degree does:

- Provide an opportunity for student and engineering alumni professional development
- Address regional private and public sector needs for a graduate level technically-trained workforce
- Strengthen the regional economic base and attractiveness as a place to live and work for engineering professionals
- Offer post-baccalaureate engineering education opportunities to engineers employed on the Minnesota Iron “Range”
- Provide expanded opportunities for faculty in Chemical Engineering, Civil Engineering, Electrical and Computer Engineering, Industrial Engineering and Mechanical Engineering to engage in applied research and development activities with the private and public sectors
- Enhance UMD engineering faculty career development and retention.
- Expand opportunities for external research funding from the private and public sectors.

EXTERNAL FORCES

Another major driver in offering an MEng degree is recognizing that there are changes looming on the horizon with respect to professional engineering licensure and also related to this issue is the amount of mathematics, science, and discipline-specific technical courses that can be accommodated in a standard 4-year, 128-130 semester credit undergraduate engineering program. Stated in a National Academy of Engineering report\(^{(1)}\), “It is evident that the exploding body of science and engineering knowledge cannot be accommodated within the context of the traditional four year baccalaureate degree”.

The National Council of Examiners for Engineering and Surveying (NCEES), the National body responsible for the FE and PE examinations, have promulgated the following change in the “Model Law” when working with individual State engineering licensing boards\(^{(2)}\). The change states,

“... that to sit for the PE exam a person must have either an MS from an EAC/ABET accredited program or equivalent, and 3 or more years of experience OR a BS from an EAC/ABET accredited program or equivalent, an additional 30 credit hours of acceptable coursework from approved course providers and 4 or more years of experience.”

The “Model Law” becomes effective in year 2020. Other requirements remain unchanged.

The Professional Societies have a mixed response to this NCEES “Model Law”. By far, the American Society of Civil Engineers (ASCE) is the strongest professional society supporting this “Model Law”. According to PS 465(Policy Statement 465)\(^{(3)}\),

“...the ASCE Book of Knowledge (BOK) will be fulfilled by means of formal education and experience—that is, a bachelor’s degree plus a master’s degree, or approximately 30 semester credits, and experience. Two common fulfillment paths were developed—one involving an accredited bachelor’s degree in civil engineering followed by a master’s degree, or approximately 30 semester credits of acceptable graduate-level or upper-level undergraduate courses, and the other...
using an appropriate bachelor’s degree followed by an accredited master’s degree.”

The official position of ASME is the one the ASME Board adopted April 24-25, 2008\(^4\), "ASME General Position Statement on Mandatory Educational Requirements for Engineering Licensure," which expresses ASME’s opposition to Master's or Equivalent. The position statement has been endorsed by eight other engineering organizations since its release: AIChE, ASHRAE, IESNA, IIE, ISA, SME, SNAME and TMS.

The official position of the IEEE states, “IEEE-USA neither supports nor opposes the National Council of Examiners for Engineering and Surveying (NCEES) decision to recommend that engineers who have successfully completed accredited baccalaureate-degree educational programs be required to take 30 additional hours of engineering education to become licensed, beginning in 2020. IEEE-USA recommends that NCEES work with ABET and concerned professional societies to ensure that the proposed additional education requirement is better defined, and to develop a clearly articulated process by which state licensing boards can ensure that individual applicants for licensure have met the requirement. Such actions will better serve the career needs of electrical engineers and the public need for an adequate supply of licensed professional engineers. IEEE-USA”

David L. Whitman, Ph.D., P.E., NCEES President, presented an overview of the current status of the “Model Law” at the ASEE Engineering Deans Institute, April 2010\(^6\). He is aware of the mixed responses and additional discussion is scheduled for the August NCEES meeting.

Even though the National professional societies provide a mixed message, we expect a significant number of graduates in the new UMD Civil Engineering program will want to pursue this BS + 30 option leading to eventual licensure. Career opportunities are severely limited for BS graduates who do not pass the Fundamentals of Engineering exam as the initial step leading to Professional Engineering licensure and it appears that licensure will require some type of a BS + 30. In a sense, we are being proactive in the development and offering of the MEng degree in response to these potential changes.

THE PROGRAM

Virtually all of the ASEE North Midwest Section member universities offer a variety of Master of Engineering, or similar degree monikers, with a focus on engineering or a specific discipline within engineering. In general, these programs focus on a strong emphasis towards the practice of engineering in industry, business, or government. In addition, these programs:

- Cater to a regional constituency
- Cater to place and time bound students
- Include minimal project or research components
- Have different admission requirements than a Master of Science degree program. Typically this includes undergraduate GPAs in the 2.5 to 3.0/4.0 range and consideration of post-baccalaureate professional experience
- Require a minimum of 30 post-baccalaureate semester credits

and are often, but not always, considered as a terminal degree, not directed toward continuation in a Ph. D. program.

The focus and content of the UMD MEng program is congruent with these characteristics. The requirements are similar to many other programs.

The UMD MEng degree program is primarily a coursework degree program, often referred to as a Plan C at the UMTC, with a minimum of three credits and a maximum of six credits allocated to a design project to be arranged between the Departmental Advisor and student. The 30 credits require a minimum of 14 credits at 5XXX or higher, and a cap of 6 credits on 4XXX courses. There is no requirement for a final exam above and beyond what is required in individual courses. Deviations from Table 1 must be agreed upon by the Departmental Advisor and student. The resultant Program of Study must then be approved by the Department, the SCSE MEng Director of Graduate Studies and forwarded to the UMD Office of Graduate Education for final approval.

Many classes are conveniently offered in the late afternoon or evening and many courses are offered by ITV or enhanced face-to-face at the Mesabi Range Community and Technical College in Virginia, MN as part of the Iron Range Graduate Engineering Education Program(7).

### TABLE 1 Master of Engineering Program

<table>
<thead>
<tr>
<th>Course Requirements</th>
<th>Semester Credits</th>
<th>Course Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major Plan Department: ChE, CE, ECE, ME (within MIE), IE (within MIE)</td>
<td>12 Minimum</td>
<td>5XXX or 8XXX***, Selected 4XXX courses*</td>
</tr>
<tr>
<td>Engineering Course Project within the Major Plan Department: ChE, CE, ECE, ME (within MIE), IE (within MIE)</td>
<td>3 to 6</td>
<td>5XXX to be arranged by the Departmental Advisor and student.</td>
</tr>
<tr>
<td>Other Engineering****</td>
<td>6 to 9</td>
<td>Selected 4XXX; 5XXX, 8XXX</td>
</tr>
<tr>
<td>Non Engineering**</td>
<td>3 Minimum</td>
<td>Graduate Courses-Approved Lists</td>
</tr>
<tr>
<td>TOTAL APPROVED CREDITS</td>
<td>30 Minimum</td>
<td></td>
</tr>
</tbody>
</table>

* Identical/similar courses taken as part of an undergraduate degree either at UMD or at another institution can not be repeated or applied as part of the MEng program. The Departmental Advisor and the SCSE Director of Graduate Studies will work with the student on this issue when setting up the Program of Study.

** Non-engineering courses would consist of courses approved for graduate credit by the Departments of Computer Science, Mathematics and Statistics, Physics, Chemistry, Geological Sciences, or Biology. Identical/similar courses taken as part of an undergraduate degree either at UMD or at another institution can not be repeated or applied as part of the MEng program.
The Departmental Advisor and the SCSE Director of Graduate Studies will work with the student on this issue when setting up the Program of Study.

*** In consultation with their Departmental Advisor, students may choose to include one or more 8XXX courses in their Program of Study. It should be noted that even though there are no requirements for 8XXX courses, MEng students who meet the course prerequisites for 8xxx courses in Electrical and Computer Engineering, Engineering Management, Geologic Sciences, and Computer Science will be encouraged to include these courses in their degree program.

**** Courses selected in collaboration with the Departmental Advisor.

All MEng Graduate Students will have a Departmental Advisor. Non-faculty, including members of the industrial community, are invited to collaborate and work with the student and Departmental Advisor.

Any project report or presentation requirement within the 3-6 credits of the engineering course project are at the option of the Departmental Advisor and Department.

Admission requires that an applicant has:
- Completed an undergraduate degree in an engineering program, or upon approval by the SCSE MEng Director of Graduate Studies, in a related discipline, e.g., computer science, physics, etc.
- Earned an undergraduate grade point average (GPA) of 3.00 (on a 4.0 scale) for admission. This preferred performance minimum of a 3.0*/4.0 GPA must be from an ABET accredited program or equivalent.
- Provided two letters of recommendation-academic and/or professional references

* Industrial experience and professional licensure will be considered for applicants with a grade point less than the preferred minimum

In addition:
- For international applicants whose native language is not English, a TOEFL score preferred performance minimum is 213 on the computer based test.
- The GRE score is recommended but not required

**SUMMARY**

The University of Minnesota Duluth Swenson College of Science and Engineering (SCSE) now offers a Professional Master Of Engineering degree. The MEng addresses regional private and public sector needs as well as responds to external forces in the engineering profession. This degree program is designed to provide a strong emphasis toward the practice of engineering by focusing on the development of competencies in the areas of engineering design, problem solving, and practice beyond what can be achieved in earning a Bachelor of Science degree in a given discipline. An MEng graduate is required to specify a degree designation in one of the core UMD disciplines: Chemical Engineering, Civil Engineering, Electrical and Computer Engineering, Industrial Engineering, or Mechanical Engineering.
ACKNOWLEDGEMENTS

The University of Minnesota Duluth Swenson College of Science and Engineering would like to thank:

- Iron Range Resources (IRR) Higher Education Committee for financial support.
- Northeast Higher Education District (NHED) for the support and collaboration necessary to use Mesabi Range Community and Technical College facilities.
- The following regional professional societies for their encouragement, efforts and support:
  - The American Society of Civil Engineers (ASCE)-Duluth Section 3
  - Institute of Electrical and electronics Engineers (IEEE)-Arrowhead Section
  - Duluth Engineers Club
  - Minnesota Society of Professional Engineers-Arrowhead Chapter

REFERENCES

1. Educating the Engineering of 2020, National Academy of Engineering 2005
2. Section 130.10.C.c, page 12 of NCEES Model Law.” National Council of Examiners for Engineering and Surveying
3. Civil Engineering Body of Knowledge for the 21st Century Preparing the Civil Engineer for the Future Second Edition Copyright © 2008 by the American Society of Civil Engineers
7. IRR Higher Education Committee (multiple meetings 2009 and 2010)

STANLEY G. BURNS

Dr. Burns served as ECE Department Head at the University of Minnesota Duluth from 1998-2007 and was appointed an Associate Dean in the Swenson College of Science and Engineering and Jack Rowe Professor in the Department of Electrical and Computer Engineering, May 2007. His research interests include microelectronics processing, analog circuit design, sensors, and instrumentation. Dr. Burns teaches courses in semiconductors devices, and analog electronic circuit design. Prior to that coming to UMD, he was a Professor in the Electrical and Computer Engineering Department at Iowa State University. Professor Burns has twice received the National (IEEE) Outstanding Advisor Award for his work with the Iowa State University (ISU) IEEE student branch and received the ISU College of Engineering Superior Engineering Teacher Award. He is active in the ASEE, Senior Member of IEEE, and a registered Professional Engineer in Minnesota and Iowa. He received the B.S.E.E. (1967), the M.S.E.E. (1968), and the Ph.D. (1972) from the University of Wisconsin-Madison.
The Itasca Community College Engineering – Condensed Scheduling Effects on Persistence and Time to Graduation

Bart Johnson, Ron Ulseth
Itasca Community College Engineering

Abstract

Groups within and outside engineering education are interested in student success rates and time to graduation for engineering students in order to meet the nation’s need for new engineering graduates. In 2002 Itasca Community College's Engineering program changed from a traditional 16 week semester to a "block scheduling" format with classes taught "one-at-a-time" in 4 weeks and then in the Spring of 2005 to a "two-at-a-time" in 8 weeks. This scheduling method is successful in providing students the ability to navigate through the pre-calculus and calculus sequences at different paces than in a traditional schedule yet have the ability to complete their engineering degree in four years. Students who have started their engineering education at Itasca in the block scheduling format average 8.7 semesters to completion of their bachelor’s degree in engineering with graduation rates higher than many comparable to institutions across the nation at 54%

Introduction

Throughout the nation there are many efforts underway to increase student success rates and reduce time to graduation for engineering students in order to meet the nation’s needs for engineering. Itasca’s part of this effort led to utilizing block scheduling to increase student success rates and reduce time to graduation regardless of starting math course. For a majority of engineering programs, the calculus math sequence is the key factor in the time to graduation due to the prerequisites required for engineering and physics courses. For a student to complete their engineering degree in four years, they need to start in calculus 1 in the fall of their first year and successfully complete all of their math and other STEM courses on the first attempt and in a specified order.

This study analyzes the impact of condensed scheduling on graduation rate and time to graduation in Itasca Community College’s engineering program. The study looks at two groups at Itasca:

- 4-Week Block Group – Students who started in the Fall of 2002 and Fall of 2003 and had a majority of their STEM classes taught in a 4-week block format
- 8-Week Block Group – Students who started in the Fall of 2004 and Fall of 2005 and had a majority of their STEM classes taught in a 8-week block format
Background

Itasca Community college (ICC) is a small (1000 FYE), two-year college located in Grand Rapids, Minnesota about 80 miles northwest of Duluth, Minnesota. It was founded in 1922 and has held accreditation with the North Central Association Higher Learning Commission since the mid 1970’s. ICC primarily serves students located in the northern third of the state. ICC is a member of the Minnesota State Colleges and Universities system (MnSCU) as well as a member of the Northeast Minnesota Higher Education District (NHED). The college offers a number of two year transfer and terminal programs. The college is exceptionally known (regionally and nationally) for its associate of science engineering transfer program.

The ICC engineering program is an open admissions program with approximately 1/3 of the student body ready to start their math sequence with calculus 1, 1/3 with pre-calculus, and 1/3 at a math course below pre-calculus. The program’s faculty consists of 6 engineering/physics instructors, 2 math instructors, and 1.5 chemistry instructors. The program has grown from 10 students in 1993 to 150 students in 2010 (Ulseth 2004).

Students who complete ICC’s engineering program then transfer to 4-year institutions across the nation to complete their STEM degree. A majority of the students transfer to the regional institutions with engineering programs with which Itasca has strong partnerships and articulation agreements:

- Bemidji State University
- Michigan Technological University
- Minnesota State University, Mankato – Main Campus
- Minnesota State University, Mankato – Iron Range Engineering Campus
- North Dakota State University
- University of Minnesota – Duluth
- University of Minnesota - Twin Cities
- University of North Dakota
- St. Cloud State University

ICC Engineering’s Condensed Course Model

The majority of classes at ICC are the traditional 16-week semester courses, while classes in ICC’s engineering program (engineering, math, chemistry, and physics courses) are currently delivered in a “two classes at a time” 8-week block format with two eight week blocks per semester. Students generally take two engineering, math, or science classes per block while completing one or two semester long general education courses. Each block class is scheduled for 2 hours per day, 5 days a week with flexibility for the instructor to provide “float” or non-contact days to allow for student work days or engineering program events. This scheduling format has the following attributes:

- Focus on two engineering, math, or science courses at a time
- Flexible two hour class setting to create an interactive and student-led learning environment
- Ability to complete more than one math or physics course in a semester

The ability to take more than one math or physics course in a semester provides students with the ability to “catch up” to their peers in their STEM courses. Traditionally a student who tests into
a pre-calculus course is a semester, if not a year, behind in the four year curriculum due to the math prerequisite requirements for first and second year physics and engineering courses; most importantly with the calculus 1 prerequisite. There are a multitude of scenarios for math course sequences for a student based on a student’s starting math course, performance in a particular course and potential scheduling issues such as full courses, which can cause a delay in the completion of a STEM degree in four years.

Prior to the 8-week block format students learned in a 4-week block format with one STEM class at a time with a total of 9 STEM courses in a year. The class schedule changed to an 8-week format in 2005 to address potential concerns with scheduling, illness issues, and classroom utilization.

<table>
<thead>
<tr>
<th>Starting Math Course</th>
<th>Fall 1st Year</th>
<th>Spring 1st Year</th>
<th>Fall 2nd Year</th>
<th>Spring 2nd Year</th>
<th>Fall 3rd Year</th>
<th>Spring 3rd Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculus 1</td>
<td>Calculus 1</td>
<td>Calculus 2</td>
<td>Multi-Variable Calculus</td>
<td>Differential Equations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Calculus</td>
<td>Pre-Calculus</td>
<td>Calculus 1</td>
<td>Calculus 2</td>
<td>Multi-Variable Calculus</td>
<td>Differential Equations</td>
<td></td>
</tr>
<tr>
<td>Calculus 1 - with Calculus 1 repeated</td>
<td>Calculus 1</td>
<td>Calculus 1</td>
<td>Calculus 2</td>
<td>Multi-Variable Calculus</td>
<td>Differential Equations</td>
<td></td>
</tr>
<tr>
<td>Intermediate Algebra</td>
<td>Intermediate Algebra</td>
<td>Pre-Calculus</td>
<td>Calculus 1</td>
<td>Calculus 2</td>
<td>Multi-Variable Calculus</td>
<td>Differential Equations</td>
</tr>
</tbody>
</table>

Table 1: Sample Math Course Sequences in Traditional Semester Model

<table>
<thead>
<tr>
<th>Starting Math Course</th>
<th>1st 8 Week Block</th>
<th>Spring 1st Year</th>
<th>Fall 2nd Year</th>
<th>Spring 2nd Year</th>
<th>1st 8 Week Block</th>
<th>2nd 8 Week Block</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculus 1</td>
<td>Calculus 1</td>
<td>Calculus 2</td>
<td>Multi-Variable Calculus</td>
<td>Differential Equations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Calculus</td>
<td>Pre-Calculus</td>
<td>Calculus 1</td>
<td>Calculus 2</td>
<td>Multi-Variable Calculus</td>
<td>Differential Equations</td>
<td></td>
</tr>
<tr>
<td>Calculus 1 - with Calculus 1 repeated</td>
<td>Calculus 1</td>
<td>Calculus 1</td>
<td>Calculus 2</td>
<td>Multi-Variable Calculus</td>
<td>Differential Equations</td>
<td></td>
</tr>
<tr>
<td>Intermediate Algebra</td>
<td>Intermediate Algebra</td>
<td>Pre-Calculus</td>
<td>Calculus 1</td>
<td>Calculus 2</td>
<td>Multi-Variable Calculus</td>
<td>Differential Equations</td>
</tr>
</tbody>
</table>

Table 2: Sample Math Course Sequences in ICC Engineering’s 8 Week Block Format
Tables 1 and 2 show the impact that block scheduling has on the ability for students to stay on a path to graduating in four years regardless of starting math class or any need to repeat a class. The scheduling itself only allows for the opportunity for students to stay on a four year track. The impact was similar in the 4-week block format. The next question is how students perform in terms of graduation rate and semesters to completion of their four year engineering degree given the condensed course models.

Data

All students who started ICC’s Introduction to Engineering courses from the Fall 2002 to present date have been tracked to evaluate their success in the condensed course format. For the 241 students who started at Itasca in the Fall of 2002 through Fall of 2005 the following data was collected:

- Starting Math Course
- Successful Completion of Calculus 1
- Successful Completion of Physics 1
- Transfer Institution
- Degree Obtained at Transfer Institution
- Total Semesters for Completion of Bachelor’s Degree in Engineering

The data was collected through transcript reviews and follow-up contacts with each of the students. The data was then compiled to evaluate:

- Graduation rates overall
- Graduation rates based upon starting math course
- Graduation rates for students who started Physics 1
- Graduation rates based upon starting math course grade
- Average semesters to graduation

Results

<table>
<thead>
<tr>
<th>Starting Academic Year</th>
<th># of Students Starting Intro to Engineering</th>
<th>STEM Degrees</th>
<th>% Completion of STEM Bachelors Degree</th>
<th>Start Physics 1 &amp; Completion of Degree</th>
<th>Calculus 1 as 1st Math Course</th>
<th>Pre-Calc or Int. Algebra as 1st Math Course</th>
<th>Regardless of 1st Math Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>60</td>
<td>39</td>
<td>65%</td>
<td>80%</td>
<td>8.5</td>
<td>8.9</td>
<td>8.7</td>
</tr>
<tr>
<td>2003</td>
<td>39</td>
<td>25</td>
<td>64%</td>
<td>78%</td>
<td>8.8</td>
<td>8.7</td>
<td>8.7</td>
</tr>
<tr>
<td>2004</td>
<td>75</td>
<td>34</td>
<td>45%</td>
<td>68%</td>
<td>8.9</td>
<td>9.2</td>
<td>9.0</td>
</tr>
<tr>
<td>2005</td>
<td>67</td>
<td>33</td>
<td>49%</td>
<td>77%</td>
<td>8.5</td>
<td>8.6</td>
<td>8.5</td>
</tr>
<tr>
<td>Overall</td>
<td>241</td>
<td>131</td>
<td>54%</td>
<td>75%</td>
<td>8.7</td>
<td>8.9</td>
<td>8.7</td>
</tr>
</tbody>
</table>

Table 3: Results of the ICC Engineering Block Schedule

The results show that the ICC engineering block model is a success. The overall average degree completion rate of 54% is higher than the degree completion rates found in other national studies:
• 40.8% degree completion in engineering/engineering technologies for students entering STEM field in 1995-96 as of 2001 in Engineering (Chen 2009)
• 45% and 49% 6 year graduation rates for male and female students, respectively, starting for Southeastern University and College Coalition for Engineering Education (SUCCEED) Institutions (SUCCEED institutions award over 1/12 of all U.S. engineering degrees) (Borrego, Padilla, Zhang, Ohland, & Anderson, 2005)
• 38% in 6 year graduation rate in STEM for students starting in Fall 1993 in the Center for Institutional Data Exchange and Analysis (C-IDEA) study (Tan, 2002)
• 21% 4 year STEM graduation rate for students starting in Fall 2005 at Wright State University (Klingbeil 2010)

In comparison to these national studies, the ICC engineering program model is more successful in producing students who complete their Bachelor’s degree in engineering. ICC’s success is despite an open admissions policy with a majority of the students below calculus 1 ready in math preparation and other factors that would classify them as “at-risk” students. In addition, the students must then transfer after their two years at Itasca and deal with the issues associated with transferring to a new institution.

In addition to the higher success rate, the students are completing their degrees in a shorter amount of time. Itasca students average 8.7 semesters to completion of their STEM degree regardless of starting math course and Itasca’s open admission policy. The data also shows there is no significant difference in average semesters to completion between students with calculus 1 as their first math course and those with a lower starting math course. Figure one compares the 4, 5, and 6 year graduation rates for the Fall 2002 class at Itasca with the Fall 1996 class at the SUCCEED institutions (Borrego, Padilla, Zhang, Ohland, & Anderson, 2005).

![Figure 1: Comparison of 4, 5, & 6 Year Graduation Rates of Itasca and SUCCEED Students](image)

As shown in Figure 1, the success of the Itasca model in providing a pathway for the students to complete their degree in 4 years is evident in comparison to the SUCCEED institutions.
In addition to the condensed class schedule at Itasca, other key attributes of the ICC engineering program that contribute to the student success are:

- Student centered learning environment
- A very strong and vibrant faculty and student learning community

Another noteworthy finding is the decrease in degree completion rate as ICC’s engineering program transitioned from a 4-week to an 8-week condensed course model. Possible reasons for this decrease are:

- Decreased sense of focus on learning with multiple courses being taken at one time
- Reduced sense of a small cohort for each class

Future Work

Although the findings from this study are encouraging for the condensed block formatting at Itasca, there is still some additional work needed:

- Study of comparison groups at Itasca’s partner 4 year institutions
- Study of ICC students prior to the condensed block format
- Investigation into combining a more progressive model for math education, such as the Wright State University model, into ICC’s condensed class format
- Investigation to effect of student learning in small cohorts
- Continued investigation into more data on national averages for time to completion of degree

Conclusion

The condensed course format of Itasca Community College’s engineering program has been very successful with high student graduation rates (54%) for students achieving a bachelor’s of science in engineering in a short time frame (8.7 semester average) despite the students starting with a wide spectrum of math placements and then transferring to other institutions to complete their degree. This model is transferable to other institutions and can serve to increase the number of students finishing an engineering degree. The model can be fully adopted or could be used for select courses, such as math, and still function within a traditional 16 week class format. The potential for the ICC two year engineering model to transform engineering education is significant due to the fact that 42.0 % of degrees granted in engineering/engineering technologies are for students who started a 2-year public institution according to the July 2009 US Department of Education report “Students Who Study Science, Technology, Engineering, and Mathematics (STEM) in Postsecondary Education” (Chen 2009)
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INTRODUCTION

Tenure for college and university faculty members at small to mid-size institutions has long been a topic that has been hotly debated. Traditionally these institutions had mainly a teaching focus. In the early years tenure might have been awarded after a probationary period of five or six years and announced simply by a letter in the mail. However, since faculty abilities and interests vary widely, it was not uncommon for some faculty who were moderately or heavily involved in teaching to also produce some significant research results. Natural curiosity, student interests, capstone projects, or monetary necessity might have been the driving motivations. Many faculty members and administrators at such institutions were aware of the advantages of producing research results simply by observing the work of their peers at larger, research-oriented universities. As the years went by, the standards of these institutions were admired and gradually were put in place, at least partially, at the mid-size institutions. This might have been done simply in the name of “progress.” It might also have been done to enhance the careers of faculty at the smaller institutions and to increase their mobility. Research accomplishments and notoriety also improved the prestige of an institution. This, it seems, has also led to public recognition or acceptance of the importance of faculty research as a measure of institutional quality, especially by students and parents involved in the choice of an institution for undergraduate studies. At the same, in the United States, many applicants are available for each faculty opening. These factors have come together to increase expectations for faculty performance and the development of elaborate criteria for choosing an applicant and for the subsequent award of tenure. Measured in terms of teaching, research, and service, these expectations are rapidly becoming common throughout the educational world. These standards determine the working environment and even the lifestyle of college and university faculty members today.

There are some very important issues regarding tenure which really should be subjects of separate studies. The first is whether or not we should have tenure in our institutions at all. The second is the issue of the relationship between tenure and diversity in faculty hiring and retention. Both of these topics are worthy of extensive study and discussion, but we will reserve this for another occasion.
STANDARDS FOR TENURE

Tenure means different things to different institutions and faculty depending on their mission and history. If we model tenure in three institutional dimensions—type, location, and age—we witness a wide range of perspectives. Fundamentally, tenure can be viewed as a license to teach at a particular institution. Without tenure, the instructor’s time at the institution is limited.

Tenure is rooted in the belief in academic freedom. The instructor worthy of tenure will be protected from prejudice through a guarantee of job security. The professor’s academic and professional standing including professional integrity merits tenure.

For some institutions, especially in prior decades, achievement of tenure occurred through adequate performance of assigned teaching duties and was indicated to the instructor without the necessity for any formal application. At the other extreme, the modern research university has a comprehensive standard of intellectual production stretching from research through teaching to service.

INSTITUTIONAL PROCEDURES

Today evaluation for tenure might involve processing through three or more administrative levels and two or more faculty levels. Ideally these two lines of evaluation would be independent, allowing for a variety of viewpoints to be considered. Administratively, the unit chair evaluates the candidate, perhaps using some faculty input, and then forwards a recommendation regarding promotion or tenure to the dean (or director). The unit chair and the dean must be cognizant of unit, college (or school), and institutional promotion and tenure regulations and make recommendations that are consistent. Faculty committees at the unit, college, and institutional levels will bring a variety of perspectives, but all must be aware of expectations from different entities. Finally, the university provost (or academic vice president, chancellor) receives the administrative and faculty recommendations and makes the final decision. In the final analysis, the provost decides whether or not the candidate represents the type of faculty member who will serve the long-term needs of the institution.

A typical probationary period for tenure and promotion is six years. For subsequent promotion there is disagreement. Five years is a commonly considered minimum, but 10 years wouldn’t be unusual. For tenure, the institution usually has standards for teaching effectiveness, research productivity (stable external funding, consistent publication record), and service (to the institution, to the profession, and to the community). Problems come when the various administrators and faculty committees have different interpretations of the standards set in institutional regulations.

CANDIDATE PERSPECTIVE

Several things might contribute to a lack of interest in an academic career: the long probationary period, low salary, high workload, and financial insecurities of an academic institution. On the other hand, some might choose such a career anyway, perhaps for the following reasons: (1) the chance to participate in a research community or a community devoted to learning,
(2) appropriate intellectual gifts for such work, which makes such a career actually a liberating experience, (3) the college or university environment being the best opportunity for using one’s education, (4) the prestige of a university position, and (5) the opportunity to serve students.

Even though we might agree that an academic position is desirable, earning the Ph.D. degree doesn’t guarantee a job offer. So, anyone interested in an academic position is risking perhaps three or more years of life beyond the bachelor’s degree. Some fields might require work experience in the profession or post-doctoral studies. If the position is obtained, tenure will be either earned or denied. So, conceivably after about 10 years of study and work the individual might have failed in the pursuit of an academic career and some major or minor career change could be necessary. A negative aspect of pursuing a Ph.D. is that, if a teaching position is not available, having the Ph.D. degree might in some cases reduce employment opportunities. In the case of a traditional engineering position, the candidate might be viewed as being overqualified or too expensive.

THE CANDIDATE: TENURE REALITIES

Here we take the liberty of offering some advice to the tenure candidate. The suggestions below emphasize the candidate’s perspective while providing useful information for evaluators. Policy variations from one institution to another can be significant. The comments presented below are general observations about the process that won’t fit everyone’s situation.

1. Application for Tenure. It is important for the department chair, department promotion, tenure, and evaluation (PTE) committee, and the dean to closely follow the candidate’s career progress. Correspondingly, the candidate benefits if the unit and the college have carefully and thoughtfully written PTE documents that measure up to current institutional standards. Some institutions require an early review (third or fourth year) that should be taken very seriously. There could be an informal conversation with the chair, dean, and provost two years ahead of the planned tenure application. This should certainly happen at least with the unit chair. Some institutions require candidates to include external review letters in their dossiers. The candidate should carefully follow the institutional guidelines as to format and content of the dossier or application. Hopefully, portfolios used by successful candidates will be available for inspection by current candidates.

2. Position Description. Each candidate usually has an individual appointment letter and/or job description that should be consulted along with the PTE documents of the individual's department and college. The candidate should do quality work in quantity that is roughly equivalent to the job description (for example, research, teaching, and service percentages of 40, 40, and 20, respectively). The candidate should strive to perform at an excellent level in all three areas. Under no circumstances should research be neglected.

3. Evaluation by Peers and Administrators. We suggest that candidates not apply for early tenure or promotion unless they are clearly outstanding. At every level of evaluation almost everyone compares current candidates with those people she/he considers to be at about the same point in their career. A marginal evaluation at a lower level might not mean that the candidate will be denied tenure/promotion at the provost level.
4. **Research.** Candidates should develop their own research programs. It should be recognizable as a research effort at the candidate’s current institution. The candidate should continue doing some publishing in their original area of expertise even if they are forging ahead in a new research area at their current institution. Journal publications still are the key factor (for some institutions, one [good] or two [better] per year). Most evaluators still don’t appreciate the value of an acceptance of a paper at a prestigious conference. The “bar” is moving higher. There are some senior faculty members that suggest that we evaluate not only the quality of the journals in which we publish, but also the impact of the publications and the number of citations. As is discussed below, external funding really helps. It is growing in importance and might be a requirement at some institutions.

5. **Grants and Contracts.** A significant factor in promoting research productivity is the candidate’s ability to attract research support through grants and contracts and, correspondingly, to support research assistants (RA’s). Without RA’s, young faculty in search of tenure will have their chances of publishing limited. Faculty at mid-size institutions typically will be assigned few or no RA’s (or even teaching assistants) as compared to faculty at large research universities. This problem is partially addressed by the National Science Foundation’s Experimental Program to Stimulate Competitive Research (EPSCoR). This leads to the issue of “stimulus” or “start-up” packages. In some institutions, and in some high-demand areas (chemical engineering, for example), these packages can amount to several hundred thousand dollars or more. In a non-EPSCOR state, smaller institutions are at a disadvantage. Hopefully NSF and other government agencies will develop programs that address this issue (start-up packages) in lieu of or in addition to the programs they already have in place to help the most talented young faculty.

6. **Teaching.** Candidates should include at least two peer reviews of teaching in their portfolios. They should report on advising effectiveness (prospective students, undergraduate and graduate students, and student organizations) along with teaching effectiveness. The tenure process is ultimately for the benefit of our students since faculty research adds to the quality and prestige of the institution. Students’ careers will be significantly impacted by the public’s perception of the institution.

7. **Service.** Aside from institutional expectations, the candidate should be involved in at least one professional society. To serve at the national committee level is a worthy goal. This brings recognition to the candidate’s institution.

8. **Collegiality.** Tenure itself is no guarantee of long-term career security. Conflicts with administrators or colleagues might lead to a future resignation. To survive or thrive, the candidate must be gifted with intelligence, energy, an excellent work ethic, and the people skills required to be effective with students, faculty colleagues, and administrators. Some today refer to these people skills with the term collegiality (American Association of University Professors [AAUP], 1999; Connell & Savage, 2001). In recent years there has been some effort to include collegiality in institutional promotion and tenure documents, although this has not achieved the status traditionally given to research, teaching, and service. Although the AAUP (1999) is troubled by the effort to include collegiality as a part of the faculty evaluation process, the courts
(Connell & Savage, 2001) have consistently upheld the right of an institution to use collegiality as a significant factor in the evaluation process. The candidate should be aware of this since many administrators have been through situations in which lack of collegiality by certain faculty members was detrimental to unit productivity.

THE CANDIDATE: MAINTAINING MOBILITY

The candidate should not limit himself/herself to fulfilling the minimum criteria for tenure (or promotion), but should always try to go beyond this. The main reason is mobility: with the minimum, one can only move laterally, or downward, not upward. Institutions usually recognize tenure from other institutions when they are “higher” in prestige or reputation. But there are many circumstances in which a relatively young and brilliant faculty member wants to move to another place which has higher standards. That will not be possible unless he/she has exceeded the requirements of the current institution. This would also be true in the case of someone wishing to be an administrator.

FACULTY COMMITTEES AND ADMINISTRATORS: TENURE DECISIONS

Members of faculty promotion and tenure committees and unit administrators have the difficult task of evaluating the performance of the tenure-track faculty member and predicting the candidate’s long-term success at the institution. The tenure process is based on an underlying assumption that the behaviors learned during graduate studies and continued and improved during the tenure process will lead to a lifetime of scholarly work that will bring benefits to the institution and her students. From the perspective of the institution and its constituency, tenure involves something like a 25- to 40-year commitment. If you set an average salary for engineering faculty at one hundred thousand dollars plus overhead, that is a commitment of about five million dollars or more by the institution and its constituency. Often the constituency is the State, and it is the taxpayers’ money, so that cannot be taken lightly.

The advice to the candidate given above reflects the expectations commonly held by faculty promotion and tenure committee members and unit administrators. Correspondingly, evaluators have the obligation to do a fair and balanced evaluation of each candidate in each area of performance mentioned or hinted at in the above list.

A difficulty with earlier reviews (or even annual reviews), which in many institutions are mandatory, is that candidates generally don’t like criticism. The candidate’s response might be essentially defensive. The review then produces few useful results for the candidate’s career and might even generate a lawsuit against the institution or its administrators. This points out how important it is to clearly inform prospective faculty members about the nature of the institutional evaluation process. This should also be part of new faculty orientation. At some institutions this is dealt with through faculty mentoring programs.

A joint project of the American Council on Education (ACE), the American Association of University Professors, and United Educators Insurance Risk Retention Group produced the document Good Practice in Tenure Evaluation: Advice for Tenured Faculty, Department Chairs, and Academic Administrators (2000). This report has four main sections. Chapter 1
calls for developing and maintain clear standards and procedures for tenure evaluation. Chapters 2 and 3 call for consistency and candor in tenure decisions and evaluation. A final chapter deals with the difficult task of caring for unsuccessful candidates. The summary at the beginning of the report is must reading for all involved, and the entire report should be helpful to anyone who is concerned about the legal aspects of the tenure evaluation process.

A practical concern suggested by the ACE document is the importance of faculty and administrators being well versed in existing and approved institutional policies or regulations concerning the tenure process. Since faculty committee membership is subject to a continuing rotation, it is important that senior faculty members of such committees make an extra effort to provide what we might call an institutional memory of how tenure evaluation has and does occur. The evaluation process will change over the years, but this change should be gradual enough so that the results in the short term don’t indicate inconsistency. Administrators are perhaps in a better position to encourage consistency since usually they hold their posts much longer than do faculty members of tenure committees.

The ACE document further encourages those involved in evaluations to provide clear explanations of tenure requirements and correspondingly clear advice about how to meet tenure requirements. For example, a given academic unit might have a very specific requirement understood within the unit but not specified in the unit regulation. Such a situation could easily lead to confusion and possibly to legal problems for the institution.

SPECIAL PROBLEMS

Given the tenure picture described thus far, we must also admit that there are valuable faculty colleagues that don’t measure up to the standards we have suggested. This might be true early in their careers, at mid career, or in their final years. The common model at a research university is that the standards established during the tenure period continue throughout the faculty member’s career. Some institutions might find it difficult to hire and maintain on staff such model faculty. In some units there have been informal arrangements among collegial faculty members to hire and maintain faculty with a variety of gifts. Gifted teachers would be used as teachers. Great researchers would be given reduced teaching loads. Those with gifts of service would focus on service. All faculty members contribute to carrying the workload in the department to the best of their abilities. However, as institutional standards develop, at many institutions it has gradually become difficult to deal with the unit workload in this manner. This could be viewed as an erosion of unit autonomy. Some institutions have what are essentially per-faculty production quotas that work in favor of building units where the expectation is that each faculty member will be equally productive in all areas. Some units have dealt with this, if budgets allow, by hiring faculty with specific titles such as senior lecturer or professor of practice. These categories of faculty are outside of the tenure track. This development suggests that in future decades we can expect that faculty members who have essentially a teaching-only role will not have tenure.

A related situation exists for an institution that either is not strong in research or is committed only to teaching. A compromise should exist to save those exceptional teachers who are not that enthused (or stimulated) about research. Such institutions might give tenure to outstanding
teachers or they might award long-term contracts (five years or more) in the categories mentioned earlier: senior lecturer or professor of practice.

CONCLUSION

There is much uncertainty for the person who desires an academic career. As noted above, progress towards tenure might involve an investment of a significant portion of an individual’s life, and might, for one reason or another, lead to having to make a second career choice. For the successful candidate, we must assume that a great deal of pride and satisfaction comes with the award of tenure and having a lifetime career as a professor.

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REFERENCES


BIOGRAPHICAL INFORMATION

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A METRIC FOR ASSESSMENT OF ABET ACCREDITATION OUTCOME 3B – DESIGNING EXPERIMENTS AND ANALYZING THE RESULTS

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South Dakota State University

Introduction
The Accreditation Board for Engineering and Technology, Inc. (ABET) requires evaluation of program outcomes (POs) as part of the undergraduate engineering curricula accreditation process. Assessment under this criterion is one or more processes that identify, collect, and prepare data to evaluate the achievement of program outcomes. The Department of Civil and Environmental Engineering at South Dakota State University (SDSU) chose to use program outcomes originally established, known as the “a” through “k” outcomes. Evaluation of outcome “b”, “a graduating student should have an ability to design and conduct experiments, as well as to analyze and interpret data” was accomplished using a well-designed rubric, as is the subject of this paper. The rubric was established and administered in CEE-346L, Geotechnical Engineering Laboratory. The means of assessment was a particular laboratory experiment, One Dimensional Consolidation Test. The rubric consisted of several indicators in each of the categories: “1” – Below Expectation, “2” – Meets Expectation, and “3” – Exceeds Expectations, with a desired metric threshold score of 2 or greater. The rubric was applied to the entire class for the selected laboratory exercise during the years of 2007, 2009, and 2010. The class average was used as assessment relative to the threshold score. Data collected to date indicates the threshold score is being met; however evaluation of the metric has promulgated minor adjustments in selected areas of the curriculum to improve scores. This paper outlines the details of the assessment process, metric results, and changes to the curriculum.

Accreditation Framework
The ABET program outcomes (POs) are statements that describe what students are both expected to know and to apply at the time of graduation. This achievement indicates that the student is equipped to attain the program educational objectives. POs are measured and assessed routinely through national, university, department, and curriculum level assessment processes. The POs themselves are evaluated and updated periodically to maintain their ties to both the department’s mission and program educational objectives (PEOs). The assessment and evaluation process for the program outcomes follows a continuous improvement process. The first step is to establish program outcomes that are tied directly to the program educational objectives. The program outcomes were adopted from the ABET Engineering Criteria 2000. The POs were reviewed by the faculty in the Department of Civil and Environmental Engineering (CEE) at SDSU as well as the department’s advisory board before being adopted by the program. SDSU’s Civil Engineering program outcomes “a” through “k” are adopted from
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ABET criterion three. During the Fall semester of 2008, the CEE department faculty established the following formal methodology for reviewing and revising program outcomes. In general terms, the following outlines the Program Outcome Assessment Process (SDSU, 2009):

1. A metric or metrics will be established for a PO.
2. A threshold value will be established for each metric.
3. The value of the metric will be determined for an evaluation cycle and compared to the threshold value. Typically, the value will be determined and evaluated annually based on a 2-year moving average value of the metric.
4. For the first evaluation cycle:
   a. If the value of the metric exceeds the threshold value, then no action is necessary,
   b. If the value of the metric is less than the threshold value, then the variance is noted and possible causes for the variance will be discuss and reported by the department faculty, but no additional action is required at this time.
5. For the second evaluation cycle:
   a. For those metrics that previously exceeded the established threshold from 4a:
      i. If the value of the metric again exceeds the threshold value, then no action is necessary,
      ii. If the value of the metric is now less than the established threshold, then same response as 4b above.
   b. For those metrics that previously were less than the established threshold from 4b:
      i. If the metric now exceeds the threshold value, then no action is required,
      ii. If the value of the metric again is less than the established metric value, then the situation is considered to be a concern. The departmental faculty will at this time develop potential corrective action(s) that will be agreed upon by consensus.
6. For subsequent evaluation cycles:
   a. If the value of the metric exceeds the established threshold value, then no action is necessary,
   b. If the value of the metric exceeds the threshold value for three consecutive evaluations, the department will consider increasing the threshold value.

**Evaluation Metric for ABET Program Outcome 3b**

The CEE departmental faculty has established evaluation metrics for the assessment of the achievement of the outcomes for each of the eleven POs. These metrics include survey results, laboratory rubrics, class assignments, interviews, and results from the Fundamentals of Engineering (FE) examination. A critical threshold value for each metric has been established that is realistic and attainable, yet ambitious enough to result in continuous improvement. Evaluation of ABET PO 3b, the subject of this paper, “a graduating student should have an ability to design and conduct experiments, as well as to analyze and interpret data” was accomplished using a well-designed rubric.
Rubrics are scoring tools that are generally considered subjective assessments. A set of criteria and/or standards are created to assess a student’s performance relative to some educational outcome. The unique feature of a rubric is that it allows for standardized evaluation of each student to specified criteria, making grading more transparent and objective. A well-designed rubric allows instructors to assess complex criteria and identify areas of instruction that may require revision to achieve the desired outcome.

The literature is sparse on assessing PO 3b directly in civil engineering; therefore the literature was searched in constructing the rubric from other engineering disciplines. Felder and Brent (2003) discuss instructional techniques in meeting evaluation criteria for the various POs. The Engineering Education Assessment Methodologies and Curricula Innovation Website (2007) also discusses some strategies for PO assessment, but in a broad, general sense. McCreanor (2001) discusses assessing POs from an Industrial, Electrical, and Biomedical Engineering perspective. Winncy et al (2005) discusses meeting PO 3b from a Mechanical and Aeronautical Engineering perspective. Review of the literature revealed the following common features of rubrics: each focus on a stated objective (evaluating a minimum performance level), each use a range of evaluative scores to rate performance, and each contain a list of specific performance indicators arranged in levels that characterize the degree to which a standard has been met.

Information gleaned from the literature was coupled with the CEE department’s needs relative to our continuous improvement model established for ABET accreditation to produce an evaluation rubric. Table 1 presents the various scoring areas of the rubric. Note that reporting is not explicitly part of the Criteria 3b, but was included in the rubric none-the-less.

The final important step was to select a laboratory exercise that would allow assessment of the various areas of the rubric. The One Dimensional Consolidation Test laboratory exercise in CEE 346L – Geotechnical Engineering Laboratory was chosen for the rubric. The laboratory exercise was initially evaluated to have the expectation elements outlined in Table 1. The consolidation test is used to evaluate the load deformation properties of fine-grained soils. When an area of soil is loaded vertically the compression of the underlying soil near the center of the loaded area can be assumed to occur in only the vertical direction, that is, one-dimensionally. This one-dimensional nature of soil settlement can be simulated in a laboratory test device called a consolidometer. Using this device, one can obtain a relationship between load and deformation for a soil. Analysis of the results ultimately allows the calculation or estimation of the settlement under induced loads such as a building or other large structure.

A cutoff score of 2 (meets expectations) was established after the rubric was initially developed. The rubric was then applied to the entire class of multiple laboratory sections for the selected laboratory exercise. The class average was used as assessment relative to the cutoff score. The rubric was originally developed to be administered every other academic year. However, during SDSU’s on-site evaluation by ABET for reaccreditation in 2009, the ABET program evaluator encouraged the CEE department to administer the rubric yearly.

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<table>
<thead>
<tr>
<th><strong>Level 1</strong> Below Expectations</th>
<th><strong>Level 2</strong> Meets Expectations</th>
<th><strong>Level 3</strong> Exceeds Expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uses unsafe and/or risky procedures</td>
<td>Observes occasional unsafe laboratory procedures</td>
<td>Observes established laboratory safety plan and procedures</td>
</tr>
<tr>
<td>Does not develop a systematic plan of data gathering; experimental data collection is disorganized and incomplete</td>
<td>Development of experimental plan does not recognize entire scope of the laboratory exercise, therefore data gathering is overly simplistic (not all parameters affecting the results are measured)</td>
<td>Formulates an experimental plan of data gathering to attain the stated laboratory objectives (develops a plan, tests a model, checks performance of equipment)</td>
</tr>
<tr>
<td>Data are poorly documented</td>
<td>Not all data collected is thoroughly documented, units may be missing, or some measurements are not recorded</td>
<td>Carefully documents data collected</td>
</tr>
<tr>
<td>Does not follow experimental procedure</td>
<td>Experimental procedures are mostly followed, but occasional oversight leads to loss of experimental efficiency or loss of some data</td>
<td>Develops and implements logical experimental procedures</td>
</tr>
<tr>
<td>Cannot select the appropriate equipment and instrumentation</td>
<td>Needs some guidance in selecting appropriate equipment and instrumentation</td>
<td>Independently selects the appropriate equipment and instrumentation to perform the experiment</td>
</tr>
<tr>
<td>Does not operate instrumentation and process equipment, does so incorrectly or requires frequent supervision</td>
<td>Needs some guidance in operation of instruments and equipment</td>
<td>Independently operate instruments and equipment to obtain the data</td>
</tr>
<tr>
<td>Makes no attempt to relate data to theory</td>
<td>Needs some guidance in applying appropriate theory to data, may occasionally misinterpret physical significance of theory or variable involved and may make errors in conversions</td>
<td>Independently analyzes and interprets data using appropriate theory</td>
</tr>
<tr>
<td>Is unaware of measurement error</td>
<td>Is aware of measurement error but does not systematically account for it or does so at a minimal level</td>
<td>Systematically accounts for measurement error and incorporates error into analysis and interpretation</td>
</tr>
<tr>
<td>Seeks no additional information for experiments other than what is provided by instructor</td>
<td>Seeks reference material from a few sources - mainly from the textbook or the instructor</td>
<td>Independently seeks additional reference material and properly references sources to substantiate analysis</td>
</tr>
<tr>
<td>Reporting</td>
<td>Reporting methods are poorly organized, illogical and incomplete</td>
<td>Reporting methods are well organized, logical and complete</td>
</tr>
<tr>
<td>• Reporting methods are poorly organized, illogical and incomplete</td>
<td>• Uses unconvincing language</td>
<td>• Uses convincing language</td>
</tr>
<tr>
<td>• Uses unconvincing language</td>
<td>• Devoid of engaging points of view</td>
<td>• Makes engaging points of view</td>
</tr>
<tr>
<td>• Devoid of engaging points of view</td>
<td>• Uses inappropriate word choices for the purpose</td>
<td>• Uses appropriate word choices for the purpose</td>
</tr>
<tr>
<td>• Uses inappropriate word choices for the purpose</td>
<td>• Consistently uses inappropriate grammar structure and has frequent misspellings</td>
<td>• Consistently uses appropriate grammar structure and is free of misspellings</td>
</tr>
<tr>
<td>Evaluative score of 1</td>
<td>Evaluative score of 2</td>
<td>Evaluative score of 3</td>
</tr>
</tbody>
</table>
It should be emphasized that the rubric was used to evaluate the department’s program outcomes, not the course outcomes in the particular course where the rubric was administered. The scoring/grades that students received were assigned relative to course outcomes. Therefore, when the rubric was applied, the laboratory assignments were graded twice for each evaluation. As such, students were not aware of the assessment relative to the department’s program outcome 3b. This was by design so as not to bias student’s effort and work for the particular laboratory assignment.

**Results**

The constructed rubric was initiated in the 2006-2007 academic year. Laboratory data collection by students was performed in the laboratory on March 14 and 15, 2007 (multiple laboratory sections). Laboratory data analysis was subsequently performed by the students in the laboratory March 21 and 22, 2007. The students’ reports were submitted for grade one week later. Thirty three laboratory reports were evaluated with a resulting average score of 2.0 and a standard deviation of 0.9. Therefore, the program outcome for 2007 was achieved and a baseline for future evaluation was established. Although the cutoff was met, the class average was exactly at the cutoff score and enhancements were qualitatively deemed advisable to address the level 1 performer. Therefore, selected technical aspects of the lecture materials were enhanced to address areas of the rubric that were scored lower than desired. The technical content of the lecture materials are beyond the scope of this paper.

The rubric was re-administered in the 2008-2009 and 2009-2010 academic years. Laboratory data collection by the students was performed in the laboratory March 24, 25, and 26 in 2009 and March 23, 24, and 25 in 2010 (multiple laboratory sections). Laboratory data analysis was performed by the students the following week and handed in for grade one week later similar to the prior year. Fifty one and 33 laboratory reports were evaluated for the progressive academic years, respectively, resulting in an average score of 2.5 with a standard deviation of 0.4 for the 2008-2009 academic year and an average of 2.3 and a standard deviation of 0.6 for the 2009-2010 academic year. Given the averages increased and the standard deviations decreased over the baseline, the implemented improvements were achieved in evaluated student performance. Most notable was the improvement in the range of student performance; there were fewer students that performed at Level 1. The program outcome was considered achieved and no changes were made to the lecture materials.

**Conclusions**

A well established evaluation metric, a rubric in this case, can be used to both evaluate and enhance Program Outcomes in an ABET accreditation process. Based on the experience from the process outlined in this paper, the following conclusions are offered:

- Evaluation metrics should be conceived based on the continuous improvement process of: desired outcome → devise metrics → establish threshold and actions → first evaluation cycle and actions, if necessary → subsequent evaluation cycles and actions, if necessary.
• Evaluation metrics can take on many forms, choose the appropriate metric to measure the desired outcome.
• The rubric used to assess ABET criteria 3b allowed for evaluation relative to meeting the desired outcomes, but also allowed to review curriculum in addressing specific areas of concern.
• Stated outcomes are easily assessed by rubric scoring.

References


Biographical Information

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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.

McKenzie7 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?”, 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 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 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 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 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. 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 reported that at the University of Queensland, a Learning Management system (not named) was used for online 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 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 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, 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 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 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 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, 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 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.

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

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.

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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. Additional 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.

<table>
<thead>
<tr>
<th>EET 470/471 Capstone WebPage Rubric</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project Name</strong></td>
</tr>
<tr>
<td><strong>These items are evaluated in the Formal Project Proposal – just need to be present</strong></td>
</tr>
<tr>
<td>Present - 1</td>
</tr>
<tr>
<td>Title Block (Names, etc.)</td>
</tr>
<tr>
<td>Abstract</td>
</tr>
<tr>
<td>Charter</td>
</tr>
<tr>
<td>Formal Project Proposal</td>
</tr>
<tr>
<td>PowerPoint from Conf.</td>
</tr>
<tr>
<td><strong>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</strong></td>
</tr>
<tr>
<td>Reports</td>
</tr>
<tr>
<td>Gannt Chart</td>
</tr>
<tr>
<td>Customer Reviews</td>
</tr>
<tr>
<td>Status Reports</td>
</tr>
<tr>
<td>Deliverables Table</td>
</tr>
<tr>
<td>Justification Statement</td>
</tr>
<tr>
<td>Technical Information</td>
</tr>
<tr>
<td>System Diagram</td>
</tr>
<tr>
<td>Links to similar projects</td>
</tr>
<tr>
<td>Research List of webpages</td>
</tr>
<tr>
<td>Other pictures/drawings</td>
</tr>
<tr>
<td>Circuit schematic</td>
</tr>
<tr>
<td>Links to spec sheets</td>
</tr>
<tr>
<td>Enclosure drawings</td>
</tr>
<tr>
<td>Parts list w/ Costs</td>
</tr>
<tr>
<td>Software listings</td>
</tr>
<tr>
<td>User’s Manual</td>
</tr>
<tr>
<td><strong>Total - % of possible points</strong></td>
</tr>
</tbody>
</table>

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.

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

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 (jpeg) 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.

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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

```
RFID Tag -> Invalid ID

RFID Reader -> Microcontroller

Beverage Storage

Solenoid

Flow Meter

Dispensed Beverage

Fluid flow
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Final Project Pictures

System mounted for display

BASIC Stamp module   LCD Display   RFID module

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

Proceedings of the 2010 ASEE North Midwest Sectional Conference
Empowering Undergraduates to Design and Conduct Experiments and Attain Outcome 3b of the ABET Engineering Criteria

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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].
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.

![Diagram](image)

**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.

References


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 ($\sigma_{LU}$, $\varepsilon_{LU}$, $E_L$) and in the transverse direction ($\sigma_{TU}$, $\varepsilon_{TU}$, $E_T$), and the Poisson’s ratio in the longitudinal ($\nu_{LT}$) and transverse direction ($\nu_{TL}$).
2. Compressive Properties: same as above except for Poisson’s ratio.
3. Flexural Properties: stress-strain curves and flexural strength $\sigma_u^f$, ultimate flexural strain $\varepsilon_u^f$ and 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

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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. Members 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 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 predictable 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.

**References**

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

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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](image)

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.

STUDENTS

Experience → Grow → Make a Difference

F A C U L T Y

P A R T N E R

Sound Instructional Methods, Program Accreditation Criteria, Curriculum Design

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
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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.

<table>
<thead>
<tr>
<th>Did Extra Credit</th>
<th>Average Grade (%)</th>
<th>Grade Standard Deviation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did Not Do Extra Credit</td>
<td>83</td>
<td>9</td>
</tr>
</tbody>
</table>

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](image)

**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.

References


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 (KL=0.9).

Solution procedure:

1. Find $Q_{cold}$ (use the energy equation and Colebrook equation)

2. Knowing $Q_{cold}$, do an energy balance on a CV with $Q_{cold}$ and $Q_{hot}$ entering and $Q_{shower}$ 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 $Q_{hot}$.

3. Find $Q_{cold}$ 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 ($V_1$, $V_2$, $V_3$, $f_1$, $f_2$, $f_3$).

4. Once the new $Q_{cold}$ is known another energy balance using the $Q_{hot}$ 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$^\circ$, angle of attack of sail ($\alpha$) = 2$^\circ$.

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°. 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.

![Graph showing drag coefficient (Cd) vs. Reynolds number (Re #)].

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 2nd 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 1st 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.

\[ P_{\text{water main}} = 45 \text{ psi} \quad D_{2a} = D_{2b} = D_3 = 0.0095 \text{ m} \quad \text{let } \alpha \approx 1 \]

\[ D_{\text{water main}} = 0.128 \text{ m} \quad \epsilon_2 = 0.003 \text{ m} \]

\[ \epsilon_{\text{water main}} = 0.003 \text{ m} \quad \epsilon_3 = 0.006 \text{ m} \]

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 (P2a, P2b, P3) 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

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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
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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Ethical and Honesty Issues of Web-Based On-Line Courses Compared with Traditional Classroom Courses

Harry C. Petersen

A number of Manufacturing Engineering Technology classes have been offered both on-line and, in other different years, as traditional face-to-face classroom presentations. Thus we had the opportunity to compare on-line and web-based courses. This paper discusses how issues of student honesty and copyright laws proved to be more problematic for web-enhanced and on-line classes. We found that material placed on-line requires significantly more time to apply and re-apply to receive copyright permission, while most printed materials, DVD’s, and samples can be easily presented in face-to-face lectures without copyright problems. Exam and homework security was an issue.

Introduction

A number of Manufacturing Engineering Technology classes have been converted from traditional face-to-face classes to on-line web-based delivery, and later converted back to traditional face-to-face classroom presentations. This gave us the opportunity to compare different features and advantages/disadvantages of on-line and web-based courses. Copyright, ethical, honesty, and security issues proved to be major considerations which consumed additional time and money when offering courses on-line.

There are a number of additional time issues with web-based courses, which gave less remaining time to handle copyright, ethical, honesty, and security issues. Filming, studio time, editing and submission for uploading to our web class-management system (D2L) were the most obvious issues which consumed instructors’ time. Quality of videos is a major issue in web-based instruction, so each lesson must be reviewed prior to release, if possible. There sometimes were problems opening student submissions, and each submission took time to open, grade, and make available to students for review. If students scanned their submissions, the mailbox capacity was sometimes exceeded, and cleaning the memory took quite a bit of time. Yet, somehow we needed to find the time to handle security and copyright problems, along with handling ethical and student honesty problems.

Protecting the Privacy and Security of Student Work

Privacy and security of student work was an issue. Because University privacy rules (along with common decency) prohibit broadcasting private e-mail submissions, corrections, reprimands, and questions to all students in a class, without the opportunity for verbal classroom interaction we sometimes would answer the same questions multiple times using both telephone and e-mail. This meant that we often answered all inquiries individually. Care was required, because an e-mail sent can be forwarded to anyone by the recipient, including other students doing the same assignments. Care was (and always is) required to make sure that only the intended recipient receives a private e-mail. It is far too easy to accidently reply to all.
Copyrights and Intellectual Property

Protecting and complying with copyrights and intellectual property rights posed a major problem. Copyrighted materials require permission prior to putting it on-line, and some publishers charge a license fee. Many things are covered by copyrights. Circular 21 of the United States Copyright Office states,

“What is copyright? Copyright is a form of protection grounded in the U.S. Constitution and granted by law for original works of authorship fixed in a tangible medium of expression. Copyright covers both published and unpublished works. What does copyright protect? Copyright, a form of intellectual property law, protects original works of authorship including literary, dramatic, musical, and artistic works, such as poetry, novels, movies, songs, computer software, and architecture. Copyright does not protect facts, ideas, systems, or methods of operation, although it may protect the way these things are expressed.”

An instructor cannot depend on the ‘fair use’ doctrine to justify putting copyrighted materials on-line. Circular 21 of the United States Copyright Office warns,

“The safest course is always to get permission from the copyright owner before using copyrighted material. The Copyright Office cannot give this permission. When it is impracticable to obtain permission, use of copyrighted material should be avoided unless the doctrine of ‘fair use’ would clearly apply to the situation. The Copyright Office can neither determine if a certain use may be considered ‘fair’ nor advise on possible copyright violations. If there is any doubt, it is advisable to consult an attorney.”

When granted by the copyright holder, this permission is usually for only a limited time, so material carried over from one semester to the next required significant time and sometimes usage fees to re-apply and receive permission to put on-line. While we took reasonable efforts to protect copyrighted materials placed on-line with permission, we could not perfectly protect them. One protection was to change from downloadable Quick-time files to streaming video for copyrighted videos, but skilled students still could capture the streaming materials. In contrast, most materials, DVD’s, and samples can be easily presented in face-to-face lectures without copyright problems, security issues, licenses, or fees under the educational fair-use principles.

Security for Exams and Quizzes

There was no reasonably secure way to proctor on-line exams or quizzes, except during the single face-to-face meeting which most on-line courses required. Some local institutions and libraries might be willing to offer remote exam proctoring services. However, a fair amount of effort, and possibly even some budget will be required to set up proctoring arrangements, preparing delivery, and arranging for returning exams and quizzes in a secure manner, taking additional time and money which may not be in the budget. But without some arrangement for remote proctoring, Security of quizzes and exams cannot be guaranteed.

Without proctoring, students are able to team up for exams, share information, and use any and all disallowed resources during an on-line exam. Some students allegedly participated in “quiz teams” where four or five students gather together for each quiz or exam. On a rotating basis,
one student takes the exam, while the others watch and take notes. Then the remaining students take the exam, doing much better, of course. The students’ roles rotate from exam to exam, so each student has a chance to copy. While randomizing questions can offset this problem a bit, it still does not fully provide security.

There is temptation to reuse much of old material from earlier classes when update classes, making it easier for student dishonesty in later classes.

Conclusion

Protecting student privacy is more problematic on-line. License permission and fees for copyrighted materials usually apply for only a limited time, and require vigilant maintenance. Exam and quiz integrity requires great care, and cannot be guaranteed without the use of remote proctors. All of these additional concerns require time, and sometimes money when putting courses on-line.

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Peer Grading: Sometimes It Should Be Done

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Abstract
A problem-based method of teaching that engenders classroom discussion in lieu of lecture, and that fosters better study habits is presented. This method is especially recommended for lower-division introductory courses on technical subjects. This method is an example of the employment of inductive teaching and learning, as applied to a technical course (Prince and Felder, 2006). Goals of the method are to motivate students to keep up with the course by establishing regular periodic study times, to move the student’s focus from earning a grade to learning the material well enough to explain it to a classmate, to teach good written and verbal communication skills, and to rapidly identify weak students early in the semester so that they can be advised constructively and referred to appropriate assistance and campus offices. Results from this method, as measured by student evaluations of instruction, have been strongly positive.

Introduction
Lecture is the traditional way to teach highly technical courses. Lectures that take an entire class period have the advantage of offering lots of time to explain the details of a complex subject. Lecturing gives the instructor a sense of assurance that the students have been informed, but it is not clear that students can absorb the information presented in the lecture. On the other hand, students often to not know how to read textbooks effectively and so it may seem there is no alternative to lecturing in these technical courses.

In response to a 2006 paper by Prince and Felder (2006) in the Journal of Engineering Education, the author began experimenting with a problem-based method of teaching that engenders classroom discussion in lieu of lecture, and that fosters better study habits. Student learning outcomes have improved in terms of the enthusiasm of students for the course, the amount of material that can be covered in the course, and the early identification of struggling students. There may also be benefits in terms of retention of students in the course. It is not clear that students perform differently (better or worse) on tests during the course, but Prince and Felder’s analysis shows that that, in the long run, students retain more of what they learn.

Peer Graded Courses Contrasted with Lecture Courses
No course is purely one style or another, but for a moment, consider how a predominantly lecture-style course usually works.

Prior to the course offering, the instructor reviews available textbooks and chooses one. Then the instructor develops a set of notes for the course to coordinate with the chosen textbook. An instructor teaching the course for the first time might take notes almost exclusively from the chosen textbook. A more experienced instructor might make notes based on a composite of knowledge in the field, but will still be constrained to coordinate notes with the outline of the textbook. The textbook becomes the primary organizational vehicle for the course. However, some students will not read much of the textbook, relying instead on taking notes during class.
The instructor uses the textbook-oriented notes for the classroom lectures, usually writing the notes on a whiteboard or presenting them via computerized projection while speaking. Students copy the notes, either by hand or by using a computer. The instructor’s notes might also be made available to students as handouts or electronic files. Students may interrupt to ask questions, but they must take some initiative to do so, even if the questions are welcomed. The instructor periodically assigns homework, possibly weekly. Many students wait to the last minute to do the each assignment, then finish it in one sitting. If they encounter difficulties, there is usually not enough time to resolve them, so they turn in what they have. The homework usually is graded and turned back to the students for feedback. The students will review the homework just prior to the next test. There may also be a comprehensive final exam in the course which will prompt most students to review their homework again.

Consider how students might see the presentation of a particular subject in a lecture oriented course. Say the topic is, “Kirchhoff’s Voltage Law” (KVL). The student probably is presented with KVL for the first time via a lecture since few students read ahead in the textbook. Some number of days later, the student will work a homework problem or two on KVL. This is the student’s second exposure, but possibly days after the related lecture. Suppose now that the student does not correctly understand KVL and is unaware of the misunderstanding. He or she gets the homework wrong, but will only discover this after the homework is graded and returned, a few days after doing the homework. At this point the course has moved on to new subjects and so the homework will likely be saved away for study just before the test. Finally, the student will retrieve the homework before the test, maybe just the night before the test, and try to figure out what went wrong with the homework on KVL. This will be the student’s third encounter with the subject. Again, this encounter occurs days or even weeks after the previous encounter. If the student does not succeed in understanding KVL while studying for the test, he or she might just go ahead and take the test anyway, hoping KVL will not appear on the test. The test is graded which offers a second opportunity for giving feedback to the student on KVL. If there is a comprehensive final exam the student may encounter KVL for a fourth time when studying for the final exam.

Altogether the student encounters the subject four times (Lecture, homework, study for test, study for final exam) and twice receives feedback that can be used for improvement (homework, test).

**Peer Grading From the Instructor’s Perspective**

Now consider a different way of teaching the class that avoids long lectures and encourages discussion. Again, before the course starts the instructor reviews available textbooks and chooses one, but instead of preparing comprehensive course notes, the instructor prepares a list of homework assignments with coordinated reading assignments that cover the main subjects. The course becomes homework oriented and driven. Classroom time is used mostly to discuss homework.

Before each class, the instructor (or an assistant) grades any previously handed in homework. The instructor selects a section of the textbook for the new assignment and assigns homework that relates to that section of the textbook. The instructor posts this new assignment so that the class is aware of it. This can be done by writing it on a whiteboard at the start of class. However, course management software such as Blackboard, Desire2Learn, Moodle, etc. or a course web page can be very helpful for students since it eliminates transcription errors in
keeping track of exactly what the assignment is and it is available 24/7. The instructor also prepares a short (about 15 minute) lecture to introduce the new homework assignment. The lecture assumes the students have not read the relevant section of the textbook. Since time is short, the lecture can only motivate the students to read the section. This is done by pointing out important definitions, equations, illustrations, theories, etc. and relating these to the challenges posed by the new homework assignment. The new homework assignment will be due at the start of the next class period for “peer grading” which is a form of structured small-group discussion.

The peer grading is done during about the first ten minutes of class (assuming a 50 minute class period). At the end of the 10 minute peer grading interval the peer grade forms are turned in to the instructor and the peer graded homework is returned to the student who authored it. After class, the students have an opportunity to correct any mistakes they may have discovered during peer grading. This same assignment will be due again at the next class period for regular grading.

When the class starts, the instructor collects two sets of homework. One set is the set (the newer set) that will be peer graded. The other set (older) is the set that will be graded the normal way. Then the instructor passes the peer grading set back to random students. There must be two important exceptions: First, no student gets his or her own paper back. Second, any student who did not turn in a paper for peer grading does not get a paper to peer grade. (That student will just have to wait patiently for peer grading to end.) As the peer graded homework is passed back to random students, blank peer grading forms are passed out along with the homework. A sample peer grading form used by the author is shown in Figure 1. The grading rubric is also shown in the figure. The goal of peer grading is to establish mutual accountability for attempting the homework so that all students are prepared to discuss the homework in class.

![Figure 1, A sample peer grading form.](image)

Students are instructed to do homework on only one side of each sheet of paper so that the other side may be used by the peer grader for comments. This way the regular grader can also obviously distinguish between the student’s solution and the peer grader’s comments. After each student is done peer grading, she or he gets up, drops the peer grading form off at the instructor’s podium, and walks over to the student who was peer graded and discusses the homework with that student. The classroom becomes filled with chatter as students move about and discuss their homework. If two students have different answers, the students will naturally attempt to figure out who’s answer is right. (For a few problems they may have correct answers from the
textbook, but no complete and known correct solution methods have been given.) Each student encounters two perspectives on the homework solutions other than his or her own. One is from the student she peer graded and the other is from the person who peer graded her paper. Students usually discuss the homework by way of comparing and contrasting their solutions and techniques. At the end of the peer grading time each student will have received his or her assignment back and will have an idea of how well the assignment was done. The peer grading process also tends to plant questions in the minds of the students on some of the more difficult aspects of the assignment.

While the students are doing peer grading, the instructor can return regular graded papers to the students. When it appears that peer grading is done, the instructor should count the number of peer grading forms turned in. Occasionally a student will forget to turn a peer grading form in. Also the forms should be checked for completeness. Occasionally a student will turn in a form that is missing a grade. At this time it is an easy matter for the instructor to walk over to a student and ask for a peer grading form to be completed.

After the peer grading is done the homework is discussed by the class as a whole. One way to initiate this discussion is to ask some benign question requiring students to categorize the homework, such as, “Which question was the hardest?” (To which a smart aleck might answer, “All of them” Just ask for a second opinion from the class!) Such simple questions will usually lead quickly to substantive questions. It is usually important however to make the students ask questions that require more than a, “yes” or, “no” answer. Questions such as, “Is the answer fifteen?” should usually not be directly answered. In answering questions it is productive to show students how to set up a solution to the problem, to name theorems or definitions that are relevant, to show how to check a solution for correctness and so forth. Possible a parallel but different problem and a complete solution can be shown by way of example.

After about 25 minutes of discussion, the last 15 minutes or so of the class period should be used for introducing the next assignment.

Peer Grading From a Student’s Perspective
Consider the tasks and interactions of a typical but fictional student by the name of “Armani.” Armani also interacts with “Jessie,” and “Rory.”

After class and before the next class, Armani will correct (or finish) the most recent past homework assignment. If needed, Armani will (re)read the textbook or find help from the professor, peers, or the campus academic resource center, etc. The urgency of this task will be apparent from the peer grading event that was held on this assignment. Armani will typically have two or three days from the time of peer grading until the final due date. This will be the fourth time Armani has encountered a particular subject (say KVL) in the course. (First the introductory lecture; second, working the homework prior to peer grading; third, the peer grading event.)

Also, before the next class Armani will try the new assignment. A diligent Armani will refer to the textbook and find help as needed and invent ways to check answers. Students like that would probably thrive under any form of instruction. However, maybe Armani will skip the assigned reading in an attempt to save time. Some answers will be correctly found, but many will not. If Armani does not have enough time or perseverance to finish well, the peer grading rubric will encourage Armani to at least think about and write something down for each problem. Also,
Armani will want to seem as intelligent as possible while participating in peer grading to get some more tips on how to solve the problems. If Armani just writes garbage, Armani comes across during peer grading as a leech. A few experiences like that usually change behavior. Making homework look as intelligent as possible (with a minimum of effort) might require at least scanning the textbook for something that relates to the problems at hand. Students like this will particularly benefit from peer grading. A very few students will be totally careless. They would probably fail under any system of instruction.

In class, at the start of peer grading, by random chance Armani received Jessie’s homework for peer grading. Also Armani’s homework was given by random chance to Rory. Armani will review and possibly write remarks on Jessie’s paper, then bring it to Jessie and discuss it. Armani will have to work from memory and from what is presented on Jessie’s homework in order to grade Jessie’s homework since Armani’s paper itself is in the hands of Rory.

If Jessie’s homework is too messy to read Armani will probably talk to Jessie about that in order to understand the work and thus grade it. This helps Jessie conform to conventional standards of writing. Also, Armani and Jessie will employ the vocabulary associated with the subject and thus become more fluent in speaking about a technical subject.

Armani will also be approached by Rory and another discussion will ensue. Before the end of this discussion both Armani and Rory will have received their peer graded homework back. Then Armani and Rory might make some direct comparisons of each others papers.

When peer grading ends Armani might have seen some contrasting answers from Jessie or Rory. During the discussion period following peer grading, Armani will ask questions of the instructor to try to figure out who is right (if one of them is). A lively discussion usually ensues, which the instructor must moderate in order to give all the students and topics adequate time.

When the new homework is introduced, Armani will take out a notebook and follow the presentation closely because this is a prime time to get some tips on how to do the next homework assignment. Finally, Armani might be in a hurry to meet a friend after class. About three minutes before the end of the class Armani will start packing up and will operate a backpack zipper loudly and in a random chorus with other similarly hurried students to remind the professor that time is nearly up!

**Goals of peer grading**
The method of peer grading presented here is designed to promote four goals:

1.) To motivate the students to establish regular periodic study times for the subject and to keep up with the course effectively.

2.) To change the focus of learning from earning a grade to understanding the subject well enough to explain it to a peer. Then indirectly, to drive the students to the textbook or other sources more often and to help them identify when to seek help and to do it as early as possible.

3.) To learn how to communicate about technical subjects neatly in writing and to give students opportunities to use the technical vocabulary that goes with the course.
4.) To rapidly identify students who need help and to get them connected with campus resources and services as needed. Indirectly, helping students in a timely way improves retention in the course and in the major.

Mechanics of peer grading
Peer grading requires a different type of preparation for the semester and for each class as compared to a lecture-style course. Before the semester starts it is helpful to have stacks of blank peer grading forms printed, similar to those shown in Figure 1. It is also a good idea to set up some type of course management software so that assignments can be distributed effectively. Since two sets of homework are turned in with each class period, keeping track of what is due with each class is more difficult than with a lecture style class. The author uses a Web page for this purpose, as illustrated in Figure 2.

![Figure 2](image.png)

**Figure 2, Posting of homework assignments for a peer graded class.**

The first due date is for peer grading. The second due date is for regular grading. Assignments without dates will be assigned next, allowing students to work ahead.

The author weights each student’s average of all peer grades as 2.5% of the entire course grade and the average of the regular homework grade as 7.5% of the entire course grade. (Thus the homework as a whole is worth 10% of the course grade.) Many students request higher weighting for peer grades and for homework grades, but higher weights encourage too much copying and cheating. Even these relatively low weights adequately motivate students.

Some students will be absent from class from time-to-time for various reasons (sports, work, music, illness or medical condition, etc.) These students can be instructed to give their
homework to a classmate. The classmate then shepherds the homework through the peer grading process in class. This results in more papers to peer grade than there are students in the classroom to do the peer grading. Either the instructor can peer grade a paper, or if there are several, some students can be asked to peer grade two papers. The extra papers are then returned to the classmates who brought the papers to class.

In order to achieve the benefits of rapid feedback that peer grading can offer, it is important to grade all homework between class periods so that there is no grading backlog at all. It is also helpful to use course management software to distribute grades to students in a format that allows students to see the trends of their grades.

Finally, it is important to analyse the grades about every week during the first month or so of the class in order to rapidly identify students who need help. Figure 3 shows a spreadsheet of peer grades from an actual class the author taught. (The names have been changed.) Here a “4” represents an “A,” a “3” is a “B,” a “2” is a “C” and a blank or a dash is an “F.” After just three peer grades (one week of class) it is clear that Jana Fulton, Jean Islos and Jarad Olthof, and Jenny Quade need help. Jenny and Jana’s grades show improvement after intervention.

Figure 3, Typical peer grades from about the first three weeks of a peer graded course. Students in need of help can be rapidly identified.

Although peer grading has drawn strongly positive reviews from students on end-of-semester course evaluations, a few students will object to peer grading. These objections tend to fall into three distinct categories.

First, there may be students who simply don’t want to do homework, and will not do it, no matter what the system is. One or two of these may be geniuses who are not challenged by the material. For the sake of saving time, they will prefer to listen to the classroom discussion before attempting the assignment, if they even attempt the assignment at all. They will also be willing to suffer the loss of peer grading credit (and possibly homework credit) since they will easily make up for it with perfect or near perfect test scores. Others might not be geniuses. They
probably will fail for lack of a work ethic, no matter what style of course delivery is used. Either way, the student’s objection to peer grading is really an objection, valid or not, to work in general.

Second, occasionally a student might be socially withdrawn or insecure when discussing mistakes on homework with another student. This type of student might turn homework in for regular grading but not for peer grading. The author attempts to reach out to such students and connect them with student organizations such as ASME, IEEE, or any affinity group that might be helpful. Grades do not typically measure social skill or self confidence, but this pattern represents an opportunity for the student to improve.

Third, there are students who object to peer grading because of the frequency with which they must do homework, compared to a weekly frequency. Perhaps they have heavy work commitments for three or four weeknights in a row. This complaint can be sidestepped by posting about a week of homework in advance. Then students who raise this objection can be asked to simply work ahead as needed. A few students will take advantage of this opportunity and truly benefit. In any case, complaints are avoided.

Results

Peer grading improves the attitudes of students toward the class and consequently improves scores instructors receive on student evaluations of instruction. The students get to know each other and the instructor better on account of the increased interaction. The author’s institution has an open ended question on the prescribed evaluation from which asks, “What should the instructor continue doing?” In a recent peer graded class of 20 students, 14 responded to this question. Six of the responses were positive remarks about peer grading such as, “Peer grading is always helpful to me.” In this particular class, there were no negative responses regarding peer grading in any portions of the student evaluations. Although sometimes there may be one or two negative remarks about peer grading, these are outweighed several times over by positive remarks.

More gets done in the course. More homework problems can be assigned since the students are working at them on a regular basis. More challenging work can be assigned since there are more opportunities to offer guidance in their solutions. More textbook pages can be covered since students are directed to the text more frequently. There is much more discussion in class and the discussion tends to be more focused on challenging issues.

Students develop better study habits. They learn that help is available if you tackle the homework early enough to have time to seek help before the due date. They learn constructive methods of collaboration such as discussing the theorems or techniques needed to solve the problem rather than answering simple questions such as, “did you get 52 volts for Problem 2?” In the author’s experience, these good study habits get paid forward to other courses the students take later, even if those courses are not peer graded.

It is possible that retention could be improved by using peer grading. However the author has only had the chance to apply this technique to courses where retention was traditionally quite high, about 96% from the first week to the last week of the course. This was because the course was in the student’s major. Thus the instructor does not have enough comparable data to make a statistically meaningful statement. Certainly students who are seriously struggling can be identified within two weeks. Help can be offered earlier by giving attention to peer grades.
earned on the first two or three weeks of assignments. In the author’s experience, only about half of these identified students respond constructively. However, that is a few students saved from failure or lower grades, who otherwise would not have received help in time for it to matter.

Courses that work best with peer grading
Peer grading works best with freshman or sophomore level classes where students still are learning how to study and how to manage their time.

Peer grading also works best in class sizes of about 6 to 25 students. If there are too few students then familiarity causes less accountability. The author has used it in classes of up to about 35 students, but then the logistics of carrying out peer grading during class in about 10 minutes becomes difficult. There will be too many students desiring to ask question to give everyone a chance to participate in the discussion. The discussion time becomes harried. There will also be one or two students who become passive and allow others to ask questions for them.

The course needs a good textbook. Students will be learning primarily from the textbook and the book needs to have an adequate variety of problems to cover each main topic in the text. Sometimes supplemental information also needs to be provided in written form. There will not be enough class time to lecture over supplemental information.

Course management software such as Blackboard, Desire2Learn, Moodle, etc, can be very helpful for keeping the peer grading process well organized and for informing students of trends in their performance.

Conclusion
Students like peer grading because it keeps them on task with a regular, predictable, workload and because it helps them know when to seek help. Faculty members like peer grading because more gets done in the course, the students are happier, and course evaluations improve. Sometimes peer grading is what should be done!

Reference

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Engaging Students in Learning through Cooperative Learning Strategies

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Abstract

Engineering education faces significant challenges as it seeks to meet the demands on the engineering profession in the twenty first century. The paper focuses on classroom-based pedagogies of engagement, in general, and cooperative learning strategies in particular. The paper is a follow up to previous work by the author on viable strategies to improve the classroom environment of engineering colleges. At the start, the paper relates author’s preliminary findings on teaching-learning practices in selected engineering colleges, sheds light on the pros and cons of the lecture format, and identifies meanings and substance of different active learning protocols focusing on cooperative engagement strategies. Next, it identifies common barriers to reformation in general, and to the use of modern pedagogical skills in particular. It is also argued that any meaningful change in classroom practices today (dominated by traditional lecture-based methods) must be mandated and supported by the university administration. What is necessary to create a change, is for the department or college, to have a comprehensive and integrated set of components: clearly articulated expectations, opportunities for faculty to learn about new pedagogies, and an equitable reward system.

Introduction

“To teach is to engage students in learning.” This quote, from Education for Judgment by Christenson et al (1991), captures the meaning of the art and practice of pedagogies of engagement. The theme advocated here is that student involvement is an essential aspect of meaningful learning. Also, engaging students in learning is principally the responsibility of the instructor, who should become less an imparter of knowledge and more a designer and a facilitator of learning opportunities. In other words, the real challenge in college teaching is not trying to cover the material for the students, as many of us practice today; but rather uncovering the material with the students! This is a call for all faculty involved with teaching engineering courses, and those who develop, and implement engineering programs, to consider not only the content that make up an engineering degree, but also how students engage with these materials. It is primarily a call to search for proper tools that can be deployed to stimulate learning.

In moving forward, there are numerous tools available to select from, including the models predicated on cooperation; i.e., working together to accomplish shared goals. Within cooperative

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activities, individuals seek outcomes that are beneficial to them and to all other group members (Smith et al 1981; Johnson et al 1991). Cooperative learning researchers and practitioners have shown that positive peer relations are essential to success in college. The positive interpersonal relationships promoted through cooperative learning are regarded as crucial to today’s learning communities. They reduce uncertainties and increase the quality of social adjustment and integration into college life. Isolation and alienation, on the other hand, often lead to failure. Two major reasons for dropping out of college are: failure to establish a social network of classmates and failure to become academically involved in classes (Mckeachie et al 1986; Tinto 1994).

The purpose here is to renew the call for deployment of more effective instructional strategies in the classroom, stressing on cooperative learning practices as a viable alternative to the traditional (low-interaction lecture-based) environment that has gripped the engineering education in most institutions, for decades. The paper sheds light on: theoretical roots, current practices, and suggestions for redesigning classes-if need be- to help break the traditional lecture dominant pattern when cooperative learning protocols are deployed. The paper shows how cooperative learning can advance academic success, quality of relationships, and psychological adjustments and attitudes toward the college experience. A number of relevant questions do come to mind, including: What needs to be done to move the process forward? What are the key components of successful deployment of active learning in general and cooperative learning in particular? How to foster and expand the community of engineering faculty who decide to use cooperative learning? What plans/resources needed to institutionalize pedagogies of engagement including cooperative learning, at the department or college level? Achieving change needed does require a collective effort by all involved, namely: the institution, the faculty, and the students.

Teaching/Learning Practices Today: Findings through Interviews

To get first-hand information on teaching practices in selected colleges, the author arranged to meet with faculty members and administrators from various engineering colleges, in an effort to learn, first hand, about current teaching and learning practices, and, instructors’ views on ways to improve the classroom environment. A total of 24 faculty members were receptive and responded voluntarily – on a rather short notice - and expressed their views orally, supplemented with written statements. The main headings/questions raised by the author, during the interviews, were:

- Have you been exposed to active teaching/learning strategies, and have you kept up with recent developments in the arena of pedagogies of engagement?
- Are you willing and able to deploy any of those strategies (pedagogies of engagement) if and when the need arises?
- If you were to select one such strategy which one would it be? And why?
- Preliminary information reveals that strategies of engagement are seldom used; and if at all, only by a few and on a limited basis? Why?
- Do you believe that active learning strategies should be deployed in your department and/or college? And if so, what are the barriers?
- Based on your experience, what would you suggest to add or change in your teaching strategies that would improve the classroom environment?

While answers to the above noted questions varied considerably from one member to the next; there were, nonetheless, some agreements amongst many, on certain issues that would be worthy
of consideration. The general consensus of views/opinions expressed by the majority of the faculty interviewed by the author asserts and/or amplifies the following points: 

**First**, nearly all faculty members have been exposed to one form or another of *active learning* through workshops and seminars offered at their universities’ Learning Centers. Some have acquired the knowledge on their own, i.e., through their own personal endeavors. **Second**, all have expressed their wish to learn more about *active learning strategies*; and most do not believe that they are sufficiently competent to deploy an *active learning strategy* as yet - in the courses they will be responsible for in the near future. **Third**, with regard to the strategy they would chose or deploy, the majority had no specific preference, and have argued that a specific method is best viewed as “a good choice” only when placed within a context that considers the overall experience and outcome, including: goals and objectives, the nature of the subject, and the capabilities and readiness of the students to embark on a new undertaking. **Fourth**, many have expressed their wish to improve their classroom strategies within the framework of traditional methods, arguing that there is a great deal of room for improvement within the traditional lecture approach. **Fifth**, some members have stressed the point that the success of any *active learning strategy* requires students’ active participation - raising the question whether students are ready and willing to become active participants in the process? **Sixth**, most faculty members were mindful of the time and energy required to become a more effective instructor; and, at the same time, apprehensive and concerned that teaching is often undervalued in comparison to research.

The interviewed faculty members have been teaching undergraduate classes at their present institutions for a minimum of five years. Most of the classes taught by the aforementioned faculty are small size, seldom exceeding 35 students per class. The lecture format dominates the seen. There seem to be less interest (by most of the faculty interviewed) in the process by which the course content is delivered and more of a concern whether the rate of delivery would allow the instructor to finish the course on time. The views expressed, leads one to believe that it is highly unlikely that new more effective teaching-learning strategies would be deployed any time soon, unless drastic measures are undertaken. The author is more convinced now than ever, that deployment of *active learning strategies*, would happen only if the institution mandates it!

**The Pros and Cons of the Lecture Format**

When asked why he lectures, one faculty responded: “It is tradition. It was part of my training, and seems to dwell in me and seems like what I should be doing. I feel guilty when I am not lecturing” (Creed 1986). This candid statement suggests one of the great dilemmas faced by all who teach at the post-secondary level. Lecturing is virtually synonymous with teaching. It was the dominant method by which we were taught - and it is the method by which most of us teach. When discussing potential change in current teaching-learning strategies, many faculty become defensive, and discussions may quickly degenerate into heated debates where sides are clearly drawn. Over-exuberant advocates of *active learning* have, unfortunately, not been able to persuade many of us who have grown accustomed to traditional teaching. Better approaches in persuading traditionalists appear necessary. The challenge is to choose a suitable method at the appropriate time. Understanding the *pros and cons* of the lecture method is a helpful start.

Lectures have a number of characteristics that makes them, for the right subject matter, desirable in the classroom (Bonwell and Eison 1991). It does, to a great extent, depend on the abilities and experience of the lecturer. An able and committed lecturer can accomplish the following:
1. Relate the material proficiently and effectively, in a manner that reflects lecturer’s personal conviction and grasp of the subject matter;
2. Provide students with a thoughtful, scholarly role model to emulate;
3. Supplement the subject matter with current developments not yet published, or interject lecturer’s own views derived from his/her own experience whenever applicable;
4. Organize material in ways to meet the particular needs of a given audience;
5. Efficiently deliver large amounts of information, when the need arises, without confusing his/her audience;
6. Underscore key points, simplify complexities, and illustrate with facts and figures, and arrive at conclusions.

The effectiveness of the lecture varies inversely with the difficulty of the material presented, and listeners retain factual material better when presented in short sentences rather than in long sentences. Speaking extemporaneously is more effective than reading from lecture notes, and it is desirable to change the pitch, intensity, and timbre of one’s voice (Verner and Dickinson 1967). These characteristics presume that the lecturer is an enthusiastic and knowledgeable scholar. But, we realize that most campuses have a few that fit this description, and can be labeled as gifted practitioners who could keep most students interested during the formal 50-minute lecture. Even if it is assumed that most engineering lecturers possess these necessary characteristics, research has shown that the exclusive use of the lecture in the classroom constrains students’ learning.

For those instructors who would like to go beyond the traditional methods of lecturing, a number of effective strategies, promoting active learning, are available to choose from. If a faculty member is hesitant about selecting one or more of these active learning strategies, because some questions exist about its comparative effectiveness with the lecture method, he or she should consider the following: research has shown, beyond the shadow of doubt, that these strategies do deliver content as well as lectures while providing diverse presentations that enhances students’ motivation and achievement, and helps in building up desirable personal traits.

**Promoting Student Engagement Using Cooperative Learning Structure**

As noted earlier, relying solely on the traditional lecture approach, no matter how competent the lecturer is, fails to engage students in learning, thus indirectly deprives students of learning experiences and opportunities that could only materialize utilizing engagement strategies.

Under the umbrella of engagement strategies, there are numerous models available to select from, including the models predicated on cooperation - working together to accomplish shared goals. Within cooperative strategies individuals seek outcomes that are beneficial to themselves and beneficial to all group members within the class (Smith et al 1981; Johnson et al 1991). The work by Johnson, Johnson, and Smith (1991) indicates that students exhibit a higher level of individual achievement, develop positive interpersonal relationships, and achieve greater levels of academic self-esteem, when participating in a successful cooperative learning environment.

Cooperative learning practitioners have shown that positive peer relations are essential to success in college. The positive interpersonal relationships promoted through cooperative learning are regarded by most as crucial to today’s learning communities. They increase the quality of social adjustment to college life, reduce uncertainties about attending college, and increase integration into college life. Isolation and alienation, on the other hand, often lead to
failure. Two reasons for dropping out are: failure to establish a social network of classmates and failure to become academically involved in classes (Silberman 1996; Prince 2004).

Cooperation is more than being physically near other students. It is actually a state of mind. A willingness to open up to others, exchange information and views with others, and accept the fact that working together is more beneficial to all involved in the exercise. For a cooperative learning experience to be successful, it is imperative that the following be integrated into the class activity (Lowman 1980; McLeod 1996; Prince 2004):

- Positive Interdependence- Students should perceive that they need each other to complete the planned activity.
- Face to Face Interaction- Students should work together in planning, executing, and arriving at conclusions. They should share the work load, and share the credit. Thus promoting each others’ learning.
- Accountability- Each student’s role and performance is to be assessed, and the results are those of the group (and for the group). Keeping track of the contribution and knowledge gained by each member could be monitored, as well, by either testing each and every student in the group, or by randomly selecting a group member (or members) to be tested, and thus proxy for the group.
- Sharing known skills- Students who possess certain knowledge or skills (examples: computer skills, laboratory skills, data reduction skills, presentation skills) should be willing to pass it on, and/or share it with their group members.
- Collaborative Skills- Groups cannot function effectively if members do not have (be willing to learn) or use some needed social skills. These skills include leadership, decision making, trust building, and conflict management.
- Monitoring Progress- Groups need to discuss amongst themselves whether they are achieving their set goals; also, need to prioritize the scheduled activities, introduce changes if need be, solicit advice and assistance with the consent of the instructor, and maintain effective working relationships among the members.

Success in implementing cooperative learning is attributable, in large measure, to: proper planning, efforts, dedication, and foresight of the instructor. Experience definitely is a major factor. A proper start for instructors wanting to try active learning for the first time (including cooperative learning) is to step into it gradually, and to seek continuous feedback as to how the course is going and how the students feel about it. In addition, he/she can tap into documented sources, attend seminars/workshops on the subject matter, and discuss planned activities for his/her course with experienced colleagues who can offer constructive comments and advise.

Barriers to Change in the Classroom

To address adequately why most faculty have not embraced recent calls for educational reform, it is necessary first to identify and understand some common barriers to instructional change that seems to apply in America and elsewhere, and have been reported on in the literature (Bonwell and Eison 1991). Most of these barriers are applicable to engineering colleges- and include:

- The powerful influence of educational tradition,
- The discomfort and anxiety that change creates,
- Faculty self-perceptions and self-definitions of roles,
- Lack of well-defined incentives; also, lack of proper guidance to embark on the change.
There are also specific obstacles associated with the use of a new format in teaching, i.e., for example, when using *pedagogies of engagement* approach:

- The potential problem/difficulty that may result from not covering adequately the assigned course content in the limited class time available;
- The increase in the amount of preparation time;
- The lack of needed resources to proceed with the new method, when applicable;
- The difficulty of using *active learning*, or any variation thereof, in large classes.

Perhaps the single greatest barrier of all is the fact that: faculty members’ efforts in employing a new approach would involve risk- the **risk** that students would not participate. Additionally, faculty members may feel a loss of control, or be criticized for teaching in unorthodox ways.

Faculty universally “know” that their institution expects excellence in teaching, but relatively few campuses have critically examined and discussed explicitly how “excellence” is best achieved and assessed. Research has shown that faculty perceptions about the underpinnings associated with “superior teaching” clearly place “knowledge of the subject matter” well above all other considerations (Blackburn et al 1980). A provocative analysis of metaphors about teaching and learning in higher education describes the “Container- Dispenser model”(Pollio 1987).

Knowledge is a substance, material, or source of power, instructors are containers (filled with content, material, and facts), and students are vessels (wanting to be filled up). It seems apparent that faculty whose view of teaching and learning could be represented by the “Container-Dispenser model” would be especially concerned about covering content.

**A. The feedback circle in the classroom:** Faculty and students share many expectations regarding the proper role that each plays in teaching and learning- those perceptions having been formed in traditional classroom settings. For example, many faculty members are very specific about how they learned to teach - “modeling” themselves based on their own experiences from their student days. Most can not point to a powerful role model in their past who consistently and skillfully used *pedagogies of engagement* in the classroom. For this reason, if no other, it is not surprising that faculty seldom use strategies promoting engagement practices.

Students’ resistance is another element of the feedback circle. Some students will always resist the use of *pedagogies of engagement* because of their contrast to the more familiar passive listening role to which they have become accustomed. Listening to faculty talk is not only familiar to students; it is also a considerably easier one! Often, and as noted in the literature, students do communicate their displeasure with nontraditional instructional approaches, which in turn encourages the use of more traditional teaching methods (Bonwell and Eison 1991).

Students’ maturity, academic growth and intellectual development play a major part in their response to unfamiliar and novel teaching and learning strategies. The work by Perry (1968) suggests that “dualistic learners” want structured lectures in which faculty describe clearly and precisely what they need to know. Such students expect the instructor to maintain control over the class and to simply present the facts. They believe that a student’s role is to pay attention, to take notes, and to memorize the material presented. “Dualists” typically find class discussions confusing and a “waste of time.” Chances are that only in a later stage of intellectual development- the relativism period- students begin to assume responsibility for their own learning, view class participation as an exciting opportunity to exchange differing perspectives, and become willing to participate and critique each other. What would it take to entice students...
to become active participants at an early stage? Undoubtedly, pre-college exposure to pedagogies of engagement – if at all possible – would lighten the burden on faculty and students in adopting and implementing active learning pedagogies in college.

**B. Feelings of discomfort, anxiety and indecisiveness:** Experiencing some degree of anxiety in response to one’s initial attempts to try something new is probably a universal trait. So it is when faculty consider trying new and different ways of teaching. Faculty resistance to change in their classroom practices is the norm. Professors tend to be conservative, favoring old, tried-out methods and viewing innovations of any kind with considerable apprehension. Little evidence exists today to suggest that the picture has changed much in recent years. For many faculty, things are the way they are because that is the way they have always been; further, most find the majority of traditional teaching practices more comfortable than not (Bonwell and Eison 1991).

**C. The self-definition of roles:** Expectations about faculty members’ roles and responsibilities are often categorized under three areas: teaching, research, and service. Though institutional settings, climates, and prevailing practices naturally tend to vary; currently, on many, campuses considerable tension exists with regard to the relative importance that should be placed on each. “The language of the academy is revealing: professors speak of teaching loads and research opportunities, never the reverse” (Bonwell and Eison 1991). The greatest paradox of academic work today is that most of the faculty teach most of the time, but, unfortunately teaching is not the activity most rewarded by nor most valued by the system at large. These three categories do provide faculty members with the universally recognized cornerstones for personal self-definition; and the same three create inherently conflicting pressures for faculty members’ attention, time, and energy. To the extent that campuses provide greater recognition and rewards for research and research grants over teaching, the likelihood of faculty members’ seriously and significantly making efforts to improve instruction is reduced. Administrators – at department/college/ or institutional level - have always praised good teaching but rewarded research! Even professors themselves do the one (teaching) but acclaim the other (research).

**D. The lack of incentives to change:** Faculty members see few incentives to change, for several common reasons. First and foremost, is the pervasive belief that “we are all reasonably good teachers?” Second, there is a very limited financial incentive, if any, to devote time and effort acquiring alternatives to traditional approaches of classroom teaching. Third, the perception shared by most faculty that time and effort spent pursuing research and research money, is more rewarding, from an institution point of view, than time spent improving one’s teaching skills. Further, the personal costs of trying new innovations are often high, and innovations are acts of faith requiring that one believes that they will ultimately bear fruit and be worth the personal investment, often without the hope of immediate return. Given that most faculty view themselves as above average, and that change can involve high personal costs, faculty members who attempt alternatives to traditional approaches are relatively few. Therefore, little reason exists to try new approaches, particularly when one’s self-perception is: He/she is an above average teacher.

**Looking Forward?**

A root question: What is an engineering education for? – should be on the table for an evolutionary debate, referring, in particular, to the future of engineering education. What engineering students need to learn, and how can they best learn it, as well as how can engineering schools best teach it? The “How” is at the crux. Changing the status quo is never
easy, but time has come for colleges to turn a “new leaf” and begin moving in the direction of active learning strategies, in general, and cooperative learning environment in particular.

The author is convinced that unless, and until, the institution requires it, i.e., makes it “mandatory”, academics will continue to pursue their present course. While paying lip service to “teaching excellence,” most institutions do not provide clear and visible support and/or rewards for innovative teaching. Therefore, institutions have implicitly endorsed the status quo of “traditional” classroom instruction. The author believes that in addition to mandating the “change”, an effort should be made to create a climate for improvement in classroom instruction by changing the social and cultural norms that have prevailed for decades. Such an effort should permeate throughout the academic arena, re-defining the role of teaching faculty, underscoring the fact that learning is a consequence of students’ engagement with the subject matter, and emphasizing that the simultaneous presence of interdependence and accountability are essential to learning. The specifics of such an effort ought to include the following:

i) **Rid classroom teaching environment from prevailing passive approaches to learning, and plant the seeds for active learning protocols throughout the public education system.** Propagate the idea that: Student-teacher interactions are a “priori” to stimulate learning at all levels.

ii) **Provide the manpower and support necessary to “in-house” education units and/or centers that define, promote, and encourage the art of appropriate teaching, including active learning protocols.** Scholarly research about teaching, should be encouraged, valued, and discussed.

iii) **Provide instructors with clear and consistent communications about expectations regarding teaching.** Faculty become frustrated and confused when told that teaching plays a vital institutional role, but to find out that rewards are for research. Effective teaching should also be rewarded, and poor teaching needs to be remediated through training and development programs.

iv) **Encourage instructors, when using alternative instructional strategies, to meet the needs of students’ learning styles.** Students’ learning styles are inherently different (Dunn 1990).

v) **Target new instructors, in particular, and help them to make the transition from traditional methods to active learning strategies.** Young faculty must feel that it is all right to try a new strategy, even if the first trial is less than satisfactory.

Some institutions have lately attempted to meet some of the noted objectives by relying exclusively on teaching awards. This modest approach has not worked! More effective initiatives are needed to infuse a commitment to proper teaching and active learning strategies throughout the system. The real key to establishing a supportive environment for innovative teaching is to create a university-wide administrative structure that promotes, rewards, monitors, and publicizes excellence in the classroom. If and when such a structure is established, its prime mission would be to approach the different departments, and groups within the university hierarchy- seeking ideas, plans, scenarios, to translate the “mandated” change into reality. Common questions that are likely to come up include: How to get started? What steps should be taken to move forward? Who should initiate the process? What guarantees its success?

Invariably, different scenarios may be arrived at, and faculty members who have had some prior experience, and/or have the self-confidence in deploying engagement practices should be given the opportunity to lead in this effort. However, leaving change up to individual faculty members without a supportive culture that values effective teaching/learning pedagogies for classroom reformation and educational development, doesn’t work. Piecemeal efforts- an initiative here or a success story there - could result in pockets of improvements but will not change the status quo.
as a whole. What is necessary, from author’s perspective, to plant the seeds and sustain the “change”, is for the university (i.e., the department, the college, the group) to arrive at a comprehensive and integrated set of components: clearly articulated expectations, a reward system aligned with these expectations, and opportunities for faculty to acquire new pedagogies.

Concluding Remarks

To keep pace with fast changing global marketplace, engineering education has to undergo major “reformation” including revitalization of the classroom environment. There is concern among faculty, graduates and others—supported by feedback from faculty interviewed recently by the author—that current teaching practices (traditional teaching) have adversely affected outcome.

The paper reviews the pros and cons of the traditional lecture approach, sheds light on common forms of active learning most relevant for engineering faculty, identifies barriers to reformation, and argues that the introduction of classroom-based pedagogies of engagement can help break the traditional lecture–dominant pattern. One way to get the students actively involved is to adopt a cooperative learning strategy: dig below superficial levels, learn “to learn” and not just to pass the test, get to know their classmates, and build a sense of community with them. It is important that when seniors graduate they have acquired the skills needed to work cooperatively and are able to balance personal relations and be contributing members of their communities.

This is a call for engineering faculty and program developers, to consider not only the content and topics that make up an engineering degree but also how students engage with these materials. It is also a call for the faculty to learn the new ways of teaching, and strive to develop and achieve a high level of pedagogical knowledge and competence. In the dialogue between administrators and faculty, needed to bring about the change, faculty will rightfully identify barriers including the time and resources needed to embark on the change. Also, should request authorization to experiment with new ways of teaching without risking low teaching evaluations.

With regard to implementations, author’s findings assert that classroom practices today have remained, by and large, very traditional. Therefore, unless the “change” is mandated by the institution, it is highly unlikely that the classroom environment would witness any noticeable shift toward classroom engagement practices, any time soon. If and when the “change” is mandated, the challenge then will be: How to infuse the new pedagogies without causing disruptions or trigger some undesirable consequences? Said another way, is there an optimum balance between maintaining traditional lecture-based practices and the deployment, in part, of an active learning pedagogy? If so, what does the balance depend on? (Level of course? Type of course? Students’ background? Instructor’s abilities and skills?). Implementation of said “change” may have to be carried out in phases over time. “Change” will only be brought about through the determination of the leadership (deans, department heads, etc.), required support and resources, and faculty willingness to change their current classroom practices.

The myth expressed by some faculty that “I am willing but they won’t let me” is a common response from faculty members to calls for reform in education. To the contrary, and as eloquently expressed by Combs (1979): “Teachers may not be able to change the educational system, but the variations possible, within an ordinary classroom, are almost limitless.”
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Developing Academic, Professional and Life Skills in Undergraduate Engineers through an Interdisciplinary Peer-Mentoring Support System

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Minnesota State University, Mankato
Civil Engineering / Computer Science / Biological Sciences / Mathematics

1. Introduction

Undergraduate engineering programs prepare students for a career in engineering by building knowledge of fundamental engineering concepts and developing skills in engineering design. Due to limitations on program credits, broadening the student’s education beyond the required engineering coursework is typically limited to mandatory humanity and social science electives. Developing academic, professional and life skills can be a challenge due to the rigor of undergraduate engineering programs, yet these remain key factors in students’ ultimate success and satisfaction with their careers. While students are expected to develop abilities to network with peers, teachers and professionals in the field, this skill is rarely taught explicitly.

Furthermore, degree accreditation boards, such as ABET, require accredited programs to achieve outcomes which include: an ability to function on multi-disciplinary teams; an understanding of professional and ethical responsibilities; the broad education necessary to understand the impact of engineering solutions in a global and societal context; a recognition of the need for, and the ability to engage in life-long learning; and a knowledge of contemporary issues. These outcomes are difficult to fully achieve in major courses alone.

In conjunction with a National Science Foundation-sponsored scholarship grant (NSF #0631111), we have developed a program called MAX (Mentored Academic Experience) Scholars that addresses these needs. The engineering, engineering technology, math, biology and computer science students selected as MAX Scholars receive financial support and an opportunity to develop academic, professional and life skills through a weekly scholars’ seminar. Interdisciplinary group work, peer mentoring and mentored research or internship experience are also incorporated into the seminar course and scholarship requirements.

Bates et al. (2010) provided an overview of the MAX Scholars program, details on the scholarship selection process, benefits for involved faculty and suggestions for implementing a similar program at other institutions. This paper will focus on the weekly seminar attended by the MAX Scholars and discuss its key successes in facilitating interdisciplinary group work across Science, Technology, Engineering and Math (STEM) majors, building community amongst the scholars, and helping them develop academic, professional and life skills.
2. Background

The MAX Scholar program seeks to understand and address (1) the significant challenges facing students that contribute to decreased retention and to guide students through their STEM program; and (2) the need for connection and community for STEM majors across disciplines. These goals, combined with interdisciplinary experiences and overall academic and professional development, drive the structure and topics covered in the MAX Scholar seminar.

Literature, gathered from higher education, K-12, and organizational psychology, clearly supports the importance of community in influencing engagement and a broadening of cognitive performance beyond the purely technical (Goodenow, 1993a; Goodenow, 1993b; Ryan & Patrick, 2001). Engineers with a broader world view will be poised to lead valuable technical innovation in the 21st century (National Academy of Engineering, 2005).

A greater sense of connection to community, ranging from the immediate (belonging) to the broad (affiliation) level can enhance retention, thereby delivering greater numbers of engineers and STEM scientists to the technical workforce. This theory is supported by the K-12 body of literature, where belonging and membership in the school community are proven to influence dropout rates (Center for Educational Statistics, 1993). In addition, higher education research cites lack of community (isolation) as a primary reason for women to leave engineering fields (Brainard & Carlin, 1998) and connection to faculty community as a strong contributor to Hispanic student persistence in academic endeavors (Kraemer, 1997).

In contrast to the traditional view that attrition of STEM students was the result of a beneficial “weeding out” of inferior students from these difficult fields, Elaine Seymour states “We did not find switchers (from STEM majors) and non-switchers to be two different kinds of people. They did not differ by performance, motivation, or study-related behavior to any degree that was sufficient to explain why one group left and the other group stayed”. In other words, “good” and “bad” students alike leave STEM fields. Therefore, noncognitive factors must play a role. Improvements in retention, resulting from increases in connection to community, are fundamentally supported by the higher education model of social integration developed by Tinto (1975, 1987, and 1993). Furthermore, a sense of belonging can result in increased feelings of security, stronger self-concept, self-respect and coping abilities as these students move from academia to the workplace (DeNeui 2003).

3. MAX Scholars Seminar

One of the unique aspects of the MAX Scholars program is the focus on overall development of the scholarship recipients. The recipients, as defined by the program criteria, are diverse: multiple majors, male, female, nontraditional students, students with different ethnicities, religious affiliations, backgrounds, and family structure. The MAX Scholars attend a weekly seminar as part of the requirements of the program. The seminars are the primary mechanisms to build the academic, professional and life skills of the undergraduate scholars. In addition, students develop a sense of connection to the university and community amongst the scholar cohort. Finally, an investigative project completed by teams of scholars from different majors facilitates interdisciplinary discussions addressing broad science topics and builds relationships amongst scholars. The weekly seminar plays a critical role in strengthening faculty-student
interactions, facilitating peer mentoring, developing work/life balance skills, learning how to be both a leader and a member of an interdisciplinary team and building community. Figure 1 highlights the key input factors and output development for a MAX scholar.

![Figure 1: A model of the input factors and output skills gained by MSU MAX scholars.](image)

Along with interdisciplinary project work, a typical set of seminars for a semester includes:

1) Introductions and assignment of reflection papers describing students’ goals and obstacles
2) Resume formats and preparation
3) Preparing goals and small group discussion of resumes
4) Learning styles
5) Small group discussion of goals (grouped by year)
6) Job fair preparation and summer internship discussion
7) Interview skills with paired practicing
8) Mentoring
9) Guest speakers from industry and faculty
10) Study skills
11) Graduate school preparation
12) Assessing progress towards goals (grouped by year)
13) Interdisciplinary group projects
14) Work/life balance

Topics 3, 6 and 10 were all in small groups divided by major, allowing for stepping-stone peer mentoring. Other small group discussions were divided by class year or affinity groups based on learning styles, life situations or extra-curricular activities such as athletics. Several areas of scholar development achieved through the seminar are highlighted in the remainder of this section.

**Mentoring**

The MAX Scholar program strengthens faculty-student interactions through both the seminar and advising that occurs outside of the classroom. Peer mentoring (or stepping-stone mentoring) is used to address sophomores as they transition into the rigor of their advanced studies, juniors...
as they move into leadership roles and seniors as they enter the work force or graduate programs. The MAX Scholars are a leadership group that not only offer support for each other but also take on active, both formal and informal, peer advising that serves as a safety net for lower-division students. This net is typically built around study groups reinforced with active faculty mentoring and support for peer-mentoring. With the community of STEM scholars, we reinforce mentoring that is maintained after graduation.

**Interdisciplinary Teams**
The MAX Scholars are assigned a project each semester as part of the seminar course. The projects are completed in interdisciplinary teams of 3 – 4 students each. For example, a typical team consists of students with various majors such as biology, math, computer science and engineering. Member selection varies but is designed to promote interdisciplinary group interaction. In previous years, the students considered various aspects of global warming after a research presentation about plants in the Antarctic by Dr. Christopher Ruhland (MSU, Biology). Another project was inspired by assigned reading, a novel with an environmental theme. During the following semester, students discussed ethical issues related to environmental science, with framework provided by Dr. Craig Matarrese (MSU, Philosophy). The students also developed academic advising modules to be presented to first year STEM students. These modules are currently incorporated into college advising seminars available for all students. The scholars take part in leading these seminars, helping develop their communication skills and supporting outreach goals. For each project, the groups were led by seniors who were responsible for organizing final presentations.

**Professional Networking**
A LinkedIn group called “MSU MAX Scholars” was created to help current scholars, alumni of our program, and faculty stay connected. The group is especially beneficial to alumni who are launching their careers and current students looking for mentoring or internship experiences. This resource helps them quickly build their professional network and stay connected with the MAX Scholars community. Throughout the year, the seminar helps scholars build networks by hosting speakers from industry, graduate school and alumni.

**Career Placement**
Topics related to career and graduate school preparation are covered during the weekly seminar. Setting goals, reflection on progress towards them, and writing resumes are fundamental topics. Outside speakers from industry, university services and alumni discuss interviewing skills, job negotiation strategies, and preparation for their early career years.

**Research/Internships**
MAX Scholars are encouraged to participate in either a research or internship experience during their educational years. Scholars engage with faculty and industry mentors on projects that apply their discipline to real-world problems. The program facilitates this through mentoring, networking and development of career placement skills. Scholars are strongly encouraged to present their research results or internship experiences at conferences, including our university Undergraduate Research Conference. Travel funds are available and encourage presentation at regional, national or international meetings.
Presentation and Communication
Through the interdisciplinary group projects and research and internship experiences, MAX Scholars develop strong oral and written communication skills. In addition, students learn how to present for small and large groups, within and outside of their major.

Work/Life Balance
The seminar provides scholars with an opportunity to develop skills for success that extend and strengthen academic and professional development, facilitating personal development such as work/life balance skills. Seminar sessions include discussions on personal wellness such as nutrition and exercise. Active participation in a yoga session reinforces the need to maintain personal/professional balance during the rigor of academic pursuits. Each semester, the scholars are expected to attend an athletics or fine arts event on campus as a group. By “requiring” outside activities as part of the seminar work, students experience the benefit of engaging in social activities outside of their discipline and their established social networks. Additionally, we find that STEM students often strive for perfection and benefit by balancing studying with activities associated with quality of life.

Life-Long Learner
Awareness of the self as a learner and the development of metacognition improve the chances that a student will be a life-long learner. Along with projects on topics outside of their major, the seminar is used to discuss learning styles as it relates to the overall process of learning. The seminar, offered as pass/fail, provides an opportunity for the students to be engaged in learning without the pressure of receiving a letter grade. The interdisciplinary discussions on science-related topics facilitated by the group projects have been a highlight for scholars. They have enjoyed the opportunity to learn and discuss science-related topics in a stress-free (i.e., grade-free) environment. The scholars also attend the annual Nobel Conference held at a neighboring college which hosts scientific presentations by prestigious researchers from all over the nation, providing an excellent opportunity for our scholars to grow as life-long learners.

4. Conclusions
There is a synergy between the recruitment, retention and professional development aspects of MAX student scholars. Professional development fuels retention of these students as they are encouraged by the life skill development and mentoring. Research/internship experiences, networking and career placement skills increase confidence and prepare students for a professional career. As these students share their enthusiasm and confidence with incoming students, a springboard for recruitment arises. For example, one of the scholar assignments was to prepare a presentation, both written and oral, on what they are passionate about in their major and how that area is connected to other STEM disciplines. Helping students articulate this serves as both a retention and professional development effort. Similarly, our scholars give a short presentation to introductory freshman orientation classes within their major. The underlying purpose of outreach activities is to help our MAX Scholars fully invest in their STEM major and future career, but it also plays a key role in recruitment of new STEM majors.

The MAX Scholar seminar could be implemented as a professional development seminar for programs with or without associated scholarships. While it may be difficult for engineering
programs to connect with other majors, this type of program creates a space for students in biology, computer science and math as well as multiple types of engineering to interact. It offers true interdisciplinary experiences in a one credit seminar that could be more broadly incorporated into programs seeking to fulfill ABET criteria.

5. Future Enhancements

Through collaboration with the Iron Range Engineering (IRE) program and pending continuation of funding from the National Science Foundation, we plan to award approximately four scholarships per year to IRE students. Although granting MSU engineering degrees, the IRE program and its students are physically located in northern Minnesota at Mesabi Range College. These four scholarship recipients will be fully integrated into our MAX Scholars cohort. They will attend weekly seminars via interactive video feed and will participate in interdisciplinary teams. For example, a team working on a project and presentation would consist of 3 students in Mankato and 1 student in IRE. The team members will have to learn how to communicate and work together effectively despite the geographical separation. In today’s marketplace, industry teams regularly consist of members at different company and client locations. Developing skills in distance communication and working effectively with people in different geographic locations will be a valuable asset for our scholars as they enter the marketplace or graduate school.

Acknowledgments

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Understanding Individual Personality Types and Their Effect on Team Dynamics in a Senior Design Project Course

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Abstract

Prospective employers expect graduating engineers to be knowledgeable in both scientific/technical and engineering management aspects. It is often a challenge to include engineering management content in a tightly packed engineering curriculum. The challenge must be met by carefully selecting key engineering management topics and implementing them across the curriculum. The Senior Design Project course in Mechanical Engineering at UW-Platteville is one course where there is a relatively better opportunity and relevance to address some engineering management topics. Engineering management or management for that matter is broad in scope and includes knowledge in many areas such as cognitive processes, social processes, and project management processes. The course focuses on teams undertaking real world industry projects wherein effective team dynamics is very important. Personality types of individuals greatly affect team dynamics. Understanding of personality types and their effect on team dynamics contributes to the knowledge of cognitive and social processes in engineering management. This paper addresses the topic of personality types of individuals and their effect on team dynamics in the Senior Design Project course. Students are helped to understand and find their individual personality type in a 4-Level Artisan-Idealist-Rational-Guardian model and in a more detailed 16-Level model. Students also learn how to utilize the knowledge and differences of personality types amongst individuals to enhance better team dynamics while managing and solving industry projects.

The Need for Engineering Management for Engineering Students

The American Society for Engineering Management defines Engineering Management as a unique discipline that uses engineering skills and knowledge in managing large scale projects. It links all other types of engineers from civil and mechanical to chemical and electrical in accomplishing organizational results through the leadership of knowledge-workers and the appropriate application of technology. Prospective employers expect graduating engineers to be knowledgeable in both scientific/technical and engineering management aspects. It is often a challenge to include engineering management content in a tightly packed engineering curriculum. The challenge must be met by carefully selecting key engineering management topics and implementing them across the curriculum. Engineering management or management for that matter is broad in scope and includes knowledge in many areas such as cognitive processes, social processes, and project management processes. These complex relationships are well known and have been and will be studied for years. The Senior Design Project course in Mechanical Engineering at UW-Platteville is one course where there is a relatively better opportunity and relevance to address some of these engineering management topics.
The Senior Design Project course focuses on teams undertaking real world industry projects wherein effective team dynamics is very important. Personality types of individuals greatly affect team dynamics. Understanding of personality types and their effect on team dynamics contributes to the knowledge of cognitive and social processes in engineering management. This paper addresses the topic of personality types of individuals and their effect on team dynamics in the Senior Design Project course. Students are helped to understand and find their individual personality type in a 4-Level Artisan-Idealist-Rational- Guardian model and in a more detailed 16-Level model. Students also learn how to utilize the knowledge and differences of personality types amongst individuals to enhance better team dynamics while managing and solving industry projects.

**Personality Types and Instruments for their Assessment**

The earliest rigorous work on personality types dates back to the work of Carl Gustav Jung (1875-1961). Isabel Briggs Myers (1897-1980), together with her mother Katherine Cooks Briggs, extended Jung’s theory of personality types, adding two important aspects. These were the recognition of the existence and roles of the auxiliary processes and the addition of the Judging (J) and Perceiving (P) preference. Thus Jung’s eight types (2*2*2) were extended to the Myers-Briggs’ sixteen types (2*2*2*2). Sixteen “Myers-Briggs Type Indicators” (MBTI) arise from every possible combination of one selection from each pair of dichotomies as shown in Figure 1 (ISTP, ENTJ are two example types of the possible 16). The abbreviations E, I, S, N, T, F, J, and P as shown will be used throughout this paper.

<table>
<thead>
<tr>
<th>Extroversion</th>
<th>E</th>
<th>Introversion</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensing</td>
<td>S</td>
<td>Intuition</td>
<td>N</td>
</tr>
<tr>
<td>Thinking</td>
<td>T</td>
<td>Feeling</td>
<td>F</td>
</tr>
<tr>
<td>Judging</td>
<td>J</td>
<td>Perceiving</td>
<td>P</td>
</tr>
</tbody>
</table>

Figure 1

The MBTI has been and continues to be used worldwide and is an instrument developed specifically as a tool for the general population, and is therefore inherently benign. As a founding principle, no one type is any better or worse than any other and the test candidate has the final say as to his or her type designation. In its basic form, MBTI is a 93-item instrument used worldwide for psychological type classification and is available in many different languages. The MBTI has been around for over 60 years and has been used in a number of occupational settings. MBTI instrument intends to find an individual’s preference to the four dichotomies mentioned above as follows:
Putting attention and getting energy by spending more time

- in the outer world of people and things (E) or
- in the inner world of ideas and images (I)

Paying more attention to

- information that comes in through the five senses (S) or
- the patterns and possibilities seen in the received information (N)

Making decisions by putting more weight on

- objective principles and impersonal facts (T) or
- personal concerns and the people involved (F)

Liking to live in a world of a more

- structured and decided lifestyle (J) or
- flexible and adaptable lifestyle (P)

The choice between E or I is about orientation, S or N is about cognitive perceiving function, T or F is about cognitive judging function, and J or P is about attitude of the functions. Myers stated that the interaction of these orientations, functions and attitudes are what makes up the personality types.

The Keirsey Temperament Sorter II (KTSII) is an instrument developed by David Keirsey, a contemporary of Isabel Myers. The test is available online as a 70-item instrument that has only two possible responses for each item. Keirsey follows the MBTI tradition of using 16 types but condenses through a tree-like structure into four temperament groupings called Artisans, Idealists, Rationals, and Guardians. Fundamentally, Keirsey looks at the four possible combinations between abstract or concrete in communicating and cooperative or utilitarian in achieving goals. Artisans prefer concrete communication and utilitarian goal achievement traits, idealists prefer abstract and cooperative traits, rationals prefer abstract and utilitarian traits, and guardians prefer concrete and cooperative traits. Linkage of the four KTSII types to the sixteen MBTI types is another classification. Artisans prefer S and/or P, idealists prefer N and/or F, rationals prefer N and/or T, and guardians prefer S and/or J. Just like MBTI, KTSII is widely used in industry and education.

**Administering KTSII and gathering information from Senior Design Project Students**

Different ways of teaching the topic of personality types and enabling students to find out and reflect on their personality type are possible. The approach taken in the Senior Design Project course is to give out a Questionnaire shown in Figure 2 for each student to fill out first. As can be seen in the Questionnaire, Question I is answered by taking the KTSII test online and entering the result as per the test. The remaining questions II through X are answered as per the students’ personal opinions. It can be seen that question II, III, VII, VIII, IX and X directly address the principles of Keirsey’s classifications described above. Also, question IV, V, and VI address...
more-in depth aspects of Keirsey’s classification of personality types. Finally, responses to questions VII, VIII, IX and X help compose the 16-level MBTI demographic information. Please note that administering questionnaires that involve human subject research in areas such as behavioral sciences or personality types will often require permission from appropriate authorities or committees. Maintaining anonymity will also be often a strict requirement.

**QUESTIONNAIRE**

**QUESTIONS**

**QUESTION I**
What is your temperament (or personality type) as per the result of the test you took at keirsey.com?

(***Check one***)

**ARTISAN:** ____  **IDEALIST:** ____  **RATIONAL:** ____  **GUARDIAN:** ____

**QUESTION II:** In communicating, are you _________________________ (Abstract or concrete?)

**QUESTION III:** In achieving goals, are you _________________________ (Cooperative or Utilitarian)?

**QUESTION IV:** What are you most proud of about yourself? (Select ONE from the following):

- a. Of the degree to which you are graceful in action
- b. Of the degree to which you are empathic in action
- c. Of the degree to which you are competent in action
- d. Of the degree to which you are reliable in action

**QUESTION V:** What do you respect the most about yourself? (Select ONE from the following):

- a. Of the degree to which you do good deeds
- b. Of the degree to which you are daring
- c. Of the degree to which you are benevolent
- d. Of the degree to which you are autonomous

**QUESTION VI:** What are you most confident of about yourself? (Select ONE from the following):

- a. Of the degree to which you are strong willed
- b. Of the degree to which you are respectable
- c. Of the degree to which you are adaptable
- d. Of the degree to which you are authentic

**QUESTION VII:** Are you more of an extrovert (E) or an introvert (I)? ______(E or I?)

**QUESTION VIII:** Do you notice information more by Sensing (S) or by intuition (N)? ______ (S or N?)

**QUESTION IX:** Do you make decisions more by thinking (T) or by feeling (F)? _____ (T or F?)

**QUESTION X:** Would you like to live in a world run more by judging (J) or by perceiving (P)? ______ (J or P?)

Figure 2
Representative Sample KTSII Test Results for Senior Design Project Students

Results from KTSII test for one particular semester for a particular course section of students in the Senior Design project class are discussed next. It should be pointed out that the results are representative of results from past tests but several more tests in future semesters are planned to increase the rigor of the results and inferences from those results.

The results in Figure 3 below are for a group of 30 students in a particular semester section of the Senior Design Project course who took the KTSII test. The results are shown by a team-wise breakdown for team dynamics purposes besides composite results for the whole class.

<table>
<thead>
<tr>
<th>TEAM A</th>
<th>TEAM B</th>
<th>TEAM C</th>
<th>TEAM D</th>
<th>TEAM E</th>
<th>TEAM F</th>
<th>Total</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artisans</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Idealists</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Rationals</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Guardians</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>3</td>
<td>3</td>
<td>23</td>
</tr>
</tbody>
</table>

Figure 3

The composite percentage demographics of Artisans, Idealists, Rationals, and Guardians shown in the extreme right column of Figure 3 is shown as a bar chart in Figure 4 below:

Besides the tally of raw KTSII test results shown in Figures 3 and 4 above, tallies have been of student responses to Questions II, III, VII, VIII, IX, and X and their comparison to assumptions of what those responses are through the underlying theory as described earlier for the KTSII personality type outcome. A sample for one team is shown in Figure 5 next.
Team A

Students’ Own Assessment

<table>
<thead>
<tr>
<th>Member 1</th>
<th>Member 2</th>
<th>Member 3</th>
<th>Member 4</th>
<th>Member 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communicating: Abstract (A) or Concrete (C)</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Achieving Goals: Cooperative (C) or Utilitarian (U)</td>
<td>U</td>
<td>C</td>
<td>C</td>
<td>U</td>
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<tr>
<td>Extrovert (E) or Introvert (I)</td>
<td>E</td>
<td>I</td>
<td>E</td>
<td>I</td>
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<tr>
<td>Sensing (S) or Intuition (N)</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>N</td>
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<td>Thinking (T) or Feeling (F)</td>
<td>T</td>
<td>T</td>
<td>T</td>
<td>T</td>
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<tr>
<td>Judging (J) or Perceiving (P)</td>
<td>J</td>
<td>P</td>
<td>P</td>
<td>P</td>
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</table>

Test’s Assessment

<table>
<thead>
<tr>
<th>Artisan (A) or Idealist (I) or Rational (R) or Guardian (G)</th>
</tr>
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<tbody>
<tr>
<td>G</td>
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</table>

Test’s Prediction Accuracy

| 75% | 75% | 75% | 25% | 50% |

Analysis of the Results

The raw number tally and hence the percentage tally of the four personality types show that a vast majority of graduating mechanical engineering seniors in the program are of the Guardian type (77% in the sample). This has been the trend in past studies but more such studies are planned for the future to draw more robust conclusions. It has also been that the 20 to 40% balance of other types fluctuates between Artisans, Idealists, and Rationals. In the sample example, the 23% balance is made up of 17% were Artisans, 3% Idealists, and 3% Rationals. As for the test’s prediction accuracy on detailed aspects such as responses to questions II and III, and two of questions VII through X, results vary from 25% to 100% but rarely 0%. It should be noted that just one wrong prediction drops the assessment by 25% as only responses to four questions are considered. Finally, as pointed out earlier, responses to Questions VII through X help gather information on the Meyers Briggs 16-level type categorization. For the sample in question, the results tallied as shown in Figure 6 which typifies a widespread distribution.

<table>
<thead>
<tr>
<th>ISTJ: 4</th>
<th>ISFJ: 3</th>
<th>INFJ: 1</th>
<th>INTJ: 3</th>
<th>ISTP: 4</th>
<th>ISFP: 0</th>
<th>INFP: 0</th>
<th>INTP: 5</th>
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<td>ESTP: 1</td>
<td>ESFP: 0</td>
<td>ENFP: 1</td>
<td>ENTP: 1</td>
<td>ESTJ: 2</td>
<td>ESFJ: 0</td>
<td>ENFJ: 0</td>
<td>ENTP: 5</td>
</tr>
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Teaching/Learning Outcomes from the Study
Students are given back their questionnaire after results are tallied. Anonymity of the responders is maintained even to the instructor because students only put their own secret password on the back of their questionnaire so that they can pick up their particular questionnaire. The 4-level personality types as per the KTSII theory and the 16-level personality types as per the MBIT theory are then discussed with the students. For example, the preference of Artisans to be concrete in communicating and utilitarian in achieving goals as well as their preference to sensing (S) and perceiving (P) traits are shared with the students. As for the 16-level types, students are given handouts of the high-level description of the sixteen personality types and told to assess how the description for their particular type (such as ISTJ) matches their own understanding of their personality. For example, the description for ISTJ is as follows: “Serious and quiet, interested in security and peaceful living; essentially thorough, responsible, and dependable; well-developed powers of concentration; usually interested in supporting and promoting traditions and establishments; well-organized and hard working; work steadily towards identified goals; usually accomplish any task once mind is set to it.” Students find this “personal-level” assessment to be very valuable and gain a respect for the scientific nature of the study. Students also learn that their demographics are not weighted very much towards any one particular type in the 16-level categorization but heavily weighted towards the Guardian type in the 4-level categorization. Students are apprised of the implications of that dominance. For example, an intuitive idea inference from other designs could help a project which may not be identified if the whole team has a preference only towards sensory information. The effect of personality types on team dynamics are also shared with the students. The helpful outcomes of the awareness of personality types on team dynamics are emphasized. For example, when the project manager is aware that his or her team is dominated by extroverts including the project manager himself or herself, it helps the project manager to play more of the role of listener (introvert) for better team meeting outcomes. It should be pointed out that it helps the instructor also to improve the teaching methods based on the personality type study. For example, a dominant group of Guardians means that they like a more ordered process of learning. This may require that more handouts be given to supplement the lectures for instance.

**Summary and Conclusions**

The Senior Design Project course in Mechanical Engineering at UW-Platteville is one course where there is a relatively better opportunity and relevance to address some engineering management topics. The course focuses on teams undertaking real world industry projects wherein effective team dynamics is very important. Personality types of individuals greatly affect team dynamics. Understanding of personality types and their effect on team dynamics contributes to the knowledge of cognitive and social processes in engineering management. This paper addressed the topic of personality types of individuals and their effect on team dynamics in the Senior Design Project course. Results from personality type tests in a 4-Level Artisan-Idealist-Rational- Guardian model and in a more detailed 16-Level model were gathered, analyzed, and inferences drawn. The study showed a dominance of Guardian personality type in the graduating mechanical engineering student group. How students utilize the knowledge and differences of personality types amongst individuals to enhance better team dynamics while managing and solving industry projects were also discussed.
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*Proceedings of the 2010 ASEE North Midwest Sectional Conference*
Residential Wind Turbine Testing Using a Battery Charging Configuration

Vincent Winstead
Minnesota State University, Mankato

Abstract

This paper describes the efforts put toward testing and validating four residential wind turbine systems set up in battery pack charging configurations. The goals of the research project will be described along with a description of the system design for each turbine. In addition, the format and sampling techniques of the collected data will be described along with example data collected from the project. Finally, the paper concludes with a discussion of possible future projects associated with the wind turbine site and test facility.

Background

This project began in 2008 as part of a state grant intended to provide a “consumer reports” viewpoint regarding the cost, installation, functionality and suitability of a residential wind turbine system for consumers in Minnesota. The grant allowed for the purchase and installation of four different wind turbine systems on campus at a designated site with a minimum of wind obstructing trees and structures and having a small site building to be used for battery energy storage, data collection and associated electronic equipment, and for the storage of project tools. The systems were chosen based on rated power output, cost, availability, and suitability for a battery charging configuration. The original project intent was to install grid connected systems. This was later changed to reduce interactions with the campus sub-grid and to allow fully independent operation. The ability to generate power regardless of the grid status was considered a strong advantage even though the typical residential installation would incorporate a grid connect system. The four turbines were chosen from four different vendors and manufacturers and encompassed two different styles, vertical axis and horizontal axis. Two of the turbines are horizontal axis types and were installed via monopole at sixty feet (a standard height as suggested by various manufacturers.). Two of the turbines are vertical axis types and were installed via monopole at eighteen and twenty feet respectively due to manufacturer recommendation and standard installation design information. All four turbines are rated at power ranges between roughly two and three kilowatt peak outputs. The four systems are 1) Skystream 3.7 (Southwest 1 To be compliant with electrical codes, any wind turbine supplying power to the grid must be capable of being isolated under conditions of grid instability (power outages) or for maintenance. This would necessarily lead to occasions of zero power output from the turbine.

Proceedings of the 2010 ASEE North Midwest Sectional Conference
Windpower), 2) ARE 110 (Abundant Renewable Energy), 3) UGE 3kW (Urban Green Energy), 4) S322 (Helixwind).

The test data consists of wind speed, wind direction and temperature data collected at roughly twenty feet and fifty five feet and per minute resolution of turbine output power (i.e. power factor corrected power derived from sampled voltage and current) for each turbine. The data is collected and stored in a computer located at the site. There were a significant number of delays in the installation and configuration of the systems due to a number of factors outside the control of the author and therefore the amount of test data collected as of 2010 is minimal, however early results demonstrate the capability of the installed systems and completion of the project tasks is ongoing. The next section will describe the system components for each battery charging system and the methodology for data capture.

**Battery Charging Systems**

The battery charging system for each of the four turbine installations was designed in a similar fashion and closely resembles each other. The Skystream turbine system is unique amongst the other systems due to its standard “grid-connect” configuration. The other three systems are designed for a battery charging system interface and are able to connect to the electric grid using alternative manufacturer/distributor supplied equipment. The configuration for these three turbine systems will be referred to as configuration A. The Skystream turbine system will be referred to as configuration B and will be described separately. All four turbine systems were configured using a four-battery 48V nominal battery pack constructed of deep cycle sealed Absorbent Glass Mat (AGM) 200-Ah batteries. These batteries were chosen for their cost effective energy storage and low maintenance reliability. A 48V pack was chosen to fit the recommended voltage level compatible with all turbine systems. The capacity was chosen to satisfy the maximum recommended minimum Amp-hour rating provided by the manufacturers/distributors. The goal of the project does not include efficient usage of the stored energy from the turbines so the cost and reliability were the primary drivers in the choice of battery technology. All systems were installed on monopole towers at heights based on manufacturer standard design drawings and available tower hardware. The Skystream and ARE 110 turbines were supplied with 60 foot towers. The UGE 3kW was also supplied with a monopole tower but at the height of 18 feet. The Helixwind turbine was supplied without a tower but a 20 foot monopole tower was locally manufactured according to Helixwind specifications and used in the installation. All foundations were either installed (i.e. poured) as specified in manufacturer drawings or installed according to revised drawings contracted through a local engineering design firm. The nature of the project (State of Minnesota funding) required State registered engineering certification of all foundations. This was accomplished via local subcontract. In addition, all turbine system electrical installation was completed by licensed electricians. This work was accomplished by Minnesota State University electrician staff and via subcontract and included extensive cabling through conduits both external and internal to the turbine site building housing the power conversion and data measurement electronics. Each turbine
The system was earth grounded and interfaced via high voltage disconnects to the external conduit system. The disconnects are located at the base of each tower for easy access as necessary. The external (buried) conduits were routed from the disconnects to the rear of the turbine site building and up through the rear wall. Inside the turbine site building against the rear wall are an additional high voltage disconnect connecting each turbine power conversion equipment to the external conduit cabling. It is possible to isolate each turbine electrically using either in-line disconnect (one internal to the building and the other external to the building). In addition, each battery pack is isolated from each turbine system power conversion electronics through the use of a high voltage DC disconnect. All turbine systems are isolated from the grid and isolated from each other. The following two sections describe the A and B battery charging configurations.

Configuration A

The three turbines covered under this configuration generate three phase AC power. The AC voltage is rectified and bucked (i.e. voltage scaled) using custom, manufacturer provided, power converters rated for the peak turbine output. The three phase power is delivered over a range of voltages and currents to the power conversion boxes and the resulting output is regulated DC power. The output is routed to a battery charge controller which acts as a switch selectively routing power either to the 48V nominal battery pack or high power diversion load resistors if the battery capacity is near its peak. The battery charge controllers used in each system exceed the rated peak power capacity of each turbine. Each of the three systems has a dedicated diversion load capable of meeting or exceeding the capacity of the battery charge controller connected to it. See the figure below for additional detail.

![Configuration A Diagram](image1.png)

Figure 1: Configuration A Diagram
As mentioned previously, power from each turbine utilizing configuration A is delivered through two AC voltage/current disconnects prior to reaching the power converter. An additional DC voltage/current disconnect separates the battery pack from the rest of the system. In essence, each power source is connected to the system through a disconnect\(^2\) since the battery pack can act as a power source or sink depending on the direction of the current flow. On the occurrence of battery pack failure, turbine failure or power conversion electronics failure, the failed system can be isolated from the rest of the system. In addition, each of these subsystems can be maintained (as necessary) under conditions of electrical isolation.

**Configuration B**

The Skystream turbine system is covered under this configuration. This configuration is unique to the project because of its grid-connect architecture. In essence, this configuration allows the Skystream system to see a virtual “grid” connection thus allowing the turbine to activate and generate power for the battery charging system. Similar to configuration A, this configuration includes disconnects at the base of the Skystream turbine tower and at the back of the site building interior wall where all conduits deliver power from the turbines. In contrast, the Skystream turbine delivers power as two 120V\(_{\text{RMS}}\) AC line-to-neutral lines with a shared neutral line similar to the 240V\(_{\text{RMS}}\) AC delivered to a typical household. The interior disconnect then delivers power to an autotransformer. The autotransformer takes the 240VAC input and delivers 120VAC to a combined inverter/charger from Outback Power Technologies, Inc. The autotransformer is necessary since if only one 120VAC line from the turbine is used, total power output from the turbine will be limited. The inverter/charger allows bi-directional power flow and is not being used according to its intended functionality. Its intended functionality is to act as an inverter for providing AC power from a 48V nominal DC source. However, the device is also designed to provide a power flow back to a battery system (DC source) at a power level less than the inverter function capacity. This limitation on the charging power flow required that a somewhat oversized device be used. This charging capability is intended, by the manufacturer, to be used under conditions where a temporary reversal of power flow is necessary. This involves the device being used in parallel with the “grid” as a standby power source. On the occasions that battery power is necessary due to the lack of “grid” power, the charger function would be used temporarily after the “grid” became available to recharge the battery pack. In summary, the inverter/charger is intended to be used primarily as an inverter but with limited charging capability to maintain the DC power source. For this configuration, we are using the inverter/charger primarily as a charger however the inverter functionality is crucial to its utility in the configuration. The Skystream turbine is designed for “grid” connect and expects to see 120V\(_{\text{RMS}}\) AC line-to-neutral on at least one of its lines before it will close its internal contacts. In other words, the Skystream will not deliver any power without a viable AC line connection. We provide a virtual “grid” through the inverter. Once the virtual “grid” is seen by the turbine and under wind speed conditions exceeding the cut-in speed, the turbine will begin to rotate and supply power through the

\(^2\) National Electrical Code (NEC) 2008
inverter/charger to the battery system. As in configuration A, this configuration incorporates a battery charge controller in parallel with the battery pack and a diversion load exceeding the capability of the charge controller. Finally, this configuration includes a battery protection feature. A relay box is included between the autotransformer and the interior AC disconnect enabled over a limited range of battery pack voltage. If the battery pack voltage exceeds the upper voltage limit or falls below the lower voltage limit, the relay will open. Opening of the relay removes the $120V_{RMS}$ AC line-to-neutral signal to the turbine from the inverter/charger and effectively disables the turbine. See the diagram below for additional detail.

![Configuration B Diagram](image)

**Figure 2: Configuration B Diagram**

**Data Collection**

The data collected consists of weather related information including wind speed and direction at roughly 52 feet above ground level (AGL) and 20 feet AGL and outside temperature. This data is collected using two small wired weather stations interfaced to a computer within the turbine site building. The turbine output power measurements consist of output voltage and current or power. If power measurements are unavailable directly from the instrumentation, sampled voltage and current can be used to derive power factor corrected real power. Power factor corrected real power is available from two of the turbine system commercial instrumentation devices. The other two systems have yet to be instrumented although similar measurements are intended for these systems as well. The Skystream turbine system is instrumented with a T.E.D. (The Energy Detective) power meter which reports real power and RMS voltage through a USB link. The ARE 110 turbine system is instrumented with an Outback Power Technologies, Inc. charge controller with external MATE controller interface. The
MATE interface allows the measured power to be recorded via USB link to the data acquisition computer. Sampling rates for power measurements can be configured as high as one sample per second. Sampling rates for the wind and other weather data is as high as one sample per minute. Since we wish to correlate the power measurements with wind data the measurements are recorded at a sample rate of one sample per minute. This provides reasonable resolution for long term wind power data reporting. A sample of the Skystream data over the course of one day is shown below.

![Power Output on March 8, 2010](image)

Figure 3: Power and voltage measurement data from the Skystream 3.7 turbine system.

**Future Steps**

The project is in its final year and we expect all operating systems to be instrumented and providing data prior to the end of the project period. After the conclusion of the current project tasks, we plan to continue operating the turbine systems in an effort to collect long-term reliability data and to continue providing a testing facility for additional small wind turbine designs. We hope the turbine site can provide an opportunity for undergraduate and graduate student conducted research in areas related to the current project such as electric to heat energy conversion using the diversion load power or further developments in AC/DC power instrumentation.

**References**

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**Biography**

VINCENT WINSTEAD
Dr. Vincent Winstead is an associate professor in the electrical and computer engineering and technology department at Minnesota State University, Mankato. He completed his Ph.D. degree at the University of Wisconsin, Madison in Electrical Engineering.
INTRODUCTION AND HISTORY

At North Dakota State University the RF and Applied Electromagnetics Laboratory has been significantly upgraded in order to give undergraduate and graduate students the opportunity to work with new and up-to-date professional measurement equipment and software. Begun almost a half century ago, the laboratory capabilities and student experiments were originally based on measurement equipment in the VHF, UHF, and X-bands. In the early years core experiments were based on use of the slotted line and General Radio equipment at the lower frequencies and the slotted waveguide and Hewlett Packard equipment in the X-band. In time, computer analysis and design of microwave devices was added.

STUDENT EXPERIMENTS IN THE EARLY YEARS

The applied electromagnetics laboratory of the 1970’s included labs such as the following: (1) measurement of transmission-line characteristics, (2) microwave power measurements, (3) modeling capacitor fields with teledeltos (conductive) paper, and (4) impedance matching using transmission line stubs. The transmission line experiments had as objectives the measurement of line attenuation, characteristic impedance, and reflection coefficient for practical transmission lines. The creation of distortionless lines with the use of periodic loading coils could also be studied. Teledeltos paper is a two-dimensional paper with an approximately uniform resistance per square. A conductor is established by painting appropriate regions with conductive paint. Then a voltmeter is used to establish the surfaces of equipotential. The method of curvilinear squares (Hayt & Buck, 2006) could then be used to calculate the capacitance. Similar experiments were done at some universities using water in a tray as a replacement for the teledeltos paper and aluminum forms as models of the conductors. Related class demonstrations were performed using rubber-sheet models and fluid maps of potential fields (Rogers, 1954). In the fourth experiment, single- and double-stub tuners were used to match a generator to an unknown impedance. Using the slotted-line, this facilitated the visualization of standing waves along a transmission line, the measurement of the source frequency, and the measurement of the complex value of the load impedance as a function of frequency (Hayt & Buck, 2006). This latter measurement is very accurate, but can be tedious.
METALLIC WAVEGUIDE EXPERIMENTS

The experiments mentioned so far would be relevant today if the curriculum and its objectives permitted. By the 1980’s and beyond, engineering students needed to be prepared for their professional lives by going beyond experimental studies that dealt only with improving student understanding of the basic engineering science. At some universities basic electromagnetics experiments were introduced in prerequisite physics courses, and such experiments still exist today. To meet the demands of the engineering profession, the laboratory in engineering electromagnetics added basic transmission line experiments in the UHF and microwave frequency ranges (Laverghetta, 1981). Another approach was to add a cluster of metallic waveguide experiments in the X-band. These experiments included the use of slotted lines or slotted waveguides for standing-wave characterization or measurement of complex impedance values in these bands. Students would also experience direct frequency measurement, dielectric-filled waveguides, isolators, attenuation and power measurements, waveguide bends and “tees”, directional couplers, and other waveguide hardware. The key manufacturers of the day were General Radio and Hewlett Packard.

THE FREIRE-DINIZ MODEL OF THE APPLIED ELECTROMAGNETICS LABORATORY.

Almost 40 years ago, Frieire and Diniz (1973) published a textbook in Portuguese that was very significant for its intended audience (engineering students in Brazil) and for its time. The last chapter of the book dealt with suggested experiments for the electromagnetics course that could be found in American or European universities. The authors skillfully used their knowledge of electromagnetic theory to construct a set of experiments that required only a modest investment in laboratory equipment. This led to the following experiments:

1. Measurement of transmission line parameters
2. Use of the slotted transmission line to measure impedances
3. Impedance matching techniques
4. Study of the cutoff frequency of rectangular waveguides
5. Waveguide measurements using a slotted waveguide
6. Waveguides filled with dielectric material
7. Antenna pattern of the half-wave dipole.

Even today these experiments have continued usefulness. However, the pressures on the curriculum and the need to keep pace with current professional practice make it difficult to implement more than a few of the above experiments in a contemporary course. As attractive as it is, even the slotted transmission line or the slotted waveguide must be left for, perhaps, a classroom demonstration. Furthermore, the student will have to be content with a theoretical understanding of transmission line parameters. Antenna patterns remain of vital interest, so hopefully room for such a study will be made in the laboratory curriculum.
POZAR’S LABORATORY AS A MODEL

David Pozar’s laboratory at the University of Massachusetts Amherst is a model microwave engineering laboratory. It combines significant theoretical and practical elements to improve student understanding as well as important experiences in professional development for students. Pozar and Knapp (2004) present the following set of experiments in an on-line manual:

1. The slotted line (waveguide hardware, measurement of SWR, guide wavelength, impedance)
2. The vector network analyzer (one- and two-port network analysis, frequency response)
3. Active devices (the spectrum analyzer, power meter, mixers)
4. Impedance matching and tuning (stub tuner, quarter-wavelength transformer, network analyzer)
5. Cavity resonators (resonant frequency, bandwidth, frequency counter)
6. Directional couplers (insertion loss, coupling, directivity).

This laboratory is usually associated with a second course for which the traditional undergraduate electromagnetics course is a prerequisite. However, some interesting features are present. In Pozar’s first experiment, SWR and guide wavelength are considered in a waveguide context. This could also be done using traditional transmission lines and microstrip lines (Giarola & Rogers, 1978). Three experiments involve student use of network analyzers and the spectrum analyzer. Two experiments deal with impedance matching and insertion loss. These concepts and instruments should be included at least in introductory form in the first electromagnetics course.

BUDGET-PRICED INSTRUMENTS

The RF and microwave lab requires very expensive equipment and software. In situations where there are significant budgetary constraints, our students can benefit from new budget-priced RF and microwave measurement equipment and from instrumentation developed as part of senior projects. Related to this also are student-developed RF and microwave software packages for analysis and design (Fernandes, Giarola, & Rogers, 1983; Nelson & Islam, 2006; Bais & Rogers, 2008).

One example of a budget-priced instrument is the MJF Enterprises antenna analyzer (Hallas, 2005). This is not a precision instrument. However, it is priced under $500 and easily demonstrates for the student the frequency dependent character of transmission-line circuits and basic circuit components. It gives reasonable estimates of voltage standing-wave ratio.

A PC-based RF spectrum analyzer (Tracy, 2005) and a PC-based RF network analyzer (Tracy, 2006) are also available. They are low-cost instruments (under about $1,000). Their frequency ranges are limited (under 100 MHz and 260 MHz, respectively), but their accuracy is reasonable. Where only limited financial resources are available, instruments such as these could be the basis for a useful engineering lab experience.
CAD IN THE MICROWAVE ENGINEERING LABORATORY

In the 1970’s and 1980’s it was common in the microwave laboratory to introduce computer-aided design (CAD) and analysis, often using locally produced software such as PACMO (Fernandes, Giarola, & Rogers, 1983). These and similar packages could be used today, but they have often been replaced by student or trial versions of commercial software. Another package that was used at the time was MECAP, developed at the University of Maine Orono under the leadership of Dr. John C. Field (Field & Herrick, 1974). This package allowed the modeling of a wide range of transmission-line and microwave devices. A slightly more versatile package was MCAP (Gupta, Garg, & Chadha, 1981). The computer language used in PACMO, MECAP, and MCAP was FORTRAN. These were primarily analysis packages. MECAP could be driven by an optimization program that gave it a design capability. More recently, Nelson and Islam (2006) introduced MES, a Web-based package consisting of tools for analog filter design, impedance matching, and microwave network analysis. A related MATLAB-based package, CAMDS, incorporates microstrip design and analysis, waveguide analysis, impedance matching, microwave filter design, and microwave network analysis (Bais & Rogers, 2008).

In the modern lab the packages mentioned above are useful in providing an analytical solution for comparison with data taken in the lab and offer the user full access to the computer code. However, a commercial package like Agilent’s Advanced Design System (ADS) is extremely useful especially since it offers the student design tools that weren’t even dreamed of a few decades ago (Agilent Technologies, 2009).

A MODERN MICROWAVE LABORATORY

Recently the NDSU ECE Department made a commitment to significantly upgrade its RF and Applied Electromagnetics Laboratory. Today it consists of several design and measurement stations, each equipped with a computer and appropriate software. Four specialized stations provide the capability for making RF and microwave measurements of the following types: scattering parameters, time-domain reflectometry, spectral analysis, component characterization in the frequency domain, and electromagnetic interference. Currently, experiments dealing with some of these topics are integrated into the course in applied electromagnetics that is required for all undergraduate majors in Electrical Engineering or Computer Engineering. The lab is also used in the graduate courses in microwave engineering where, for example, students apply microstrip design concepts to practical devices using ADS software. Interest in the lab is further enhanced by use of the facility by senior design students. The RF and Applied Electromagnetics Laboratory is stimulating interest in a subject that is often challenging to students.

AN OUTLINE OF FOUR CURRENT MAJOR EXPERIMENTS

For the introductory undergraduate applied electromagnetics course, four major experiments are currently used at NDSU. A brief description of each is presented below, along with comments on the relationships that exist to the early experiments described above.

The first experiment (Fig. 1) is a coupled transmission lines or cross-talk experiment. This is an experiment that breaks away significantly from the experiments that were done earlier in the lab.
The content reflects interests in the department in signal transmission and electromagnetic compatibility. This experiment also reflects the general philosophy in use in the lab: the experiments are extensions of the course. The principal focus is not only to reinforce and explain theoretical concepts, but also to extend student learning beyond the lecture hall. Several types of coupled lines are studied: coupled open-wire lines, twisted pair, and coaxial lines, along with various types of grounding. The student experiences firsthand the transmission of signals through space and the potential problems this creates.

In a second experiment (Fig. 2) a study of discrete components is made. An impedance analyzer (Agilent 4395A) is employed to measure the impedance over a wide frequency range for several types of resistors, inductors, and capacitors. The student sees that one component can look like the other at different frequencies. This lab is also a departure from the experiments in use in the initial decades of the lab. On the surface it would seem that the measurements made would reinforce the theoretical studies done in the lecture hall of resistance, conductance, inductance, and capacitance. However, the student quickly learns that the mathematical models experienced in the textbook have severe limitations.

The third experiment (Fig. 3) employs a high-quality modern microwave network analyzer (Agilent E5071C) to study impedance matching using a double-stub tuner. This lab is closely linked to the experiments done by students in the lab three decades ago. The design and measurement goals are the same, but the instrumentation is radically different. The modern network analyzer produces very speedy results when compared to the earlier slotted-line approach. However, the student misses directly experiencing the standing wave on the slotted line. The students also use the network analyzer to measure the scattering parameters of microstrip devices (Giarola & Rogers, 1978). They thus experience a technology that has, for the most part, replaced the older metallic waveguide technology of the past.

Finally, in the fourth experiment (Fig. 4) a commercial spectrum analyzer (Agilent E4402B) is used along with wide bandwidth active antennas to explore the frequency spectrum experienced in the laboratory location. The students measure the radio frequency of several local broadcast stations. The analyzer also allows listening to individual stations after they are located in the ambient spectrum. This experiment introduces the students to antennas (Freire & Diniz, 1973) and to the spectrum analyzer (Pozar & Knapp, 2004). However, the primary objective is to help the students see the connection of the course material to the real world in which they live and work.
Two other stations were also added at the back of the lab (Fig. 5). These stations are multi-functional areas. The equipment at these stations can be used for circuit board manufacturing, experiments and simulations. At this point these stations have been very helpful for groups of undergraduate students in Electrical and Computer Engineering who are completing required senior design projects (i.e., capstone projects). This space has also been used for graduate and undergraduate research in applied electromagnetics. In particular, software programs on the computers have been used to simulate the radiation from printed antennas, and the test equipment at these stations has been used to develop and test various flexible sensor networks being applied to phased-array antennas.

Fig. 5 also shows a very useful table located in the center of the south end of the lab. This table has been used for meetings between advisors and undergraduate and graduate students. This area has provided a nice forum for sharing ideas about projects openly and conveniently.
CONCLUSION

The experience students have today in the RF and applied electromagnetics laboratory is the result of decades of development by many educators and researchers. The goal has always been to enhance student learning and to adequately prepare future engineers. The challenge has been and still is to choose those laboratory experiments that will be most helpful in the long-term. Some personal experience with electromagnetic waves and quality professional measurement equipment is a step in the right direction for today’s students. This combined with the creativity and energy of students and instructors alike should produce the desired results.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the helpful comments of the reviewers and the assistance of Mr. Jeffrey Erickson, NDSU ECE Department Electrical Equipment Technician, in establishing and maintaining the laboratory.

REFERENCES


**BIOGRAPHICAL INFORMATION**

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Abstract
An introductory course in vibration engineering naturally begins with the basic "building block" concepts on which a deeper understanding is built. The study of single degree of freedom lumped parameter systems lays the conceptual groundwork needed for studying the behavior of multi-degree of freedom or continuous systems. The simplest single degree of freedom vibratory system is of course the pendulum. Pendulum problems illustrate basic vibration theory very nicely, providing a simple and intuitive illustration of the building block concepts: lumped parameter models, simple harmonic motion, natural frequency, damped and undamped systems, free and forced response. Constructing these simple pendulum arrangements in a "testbed" environment and measuring the actual natural frequency provides a useful vehicle for extending theory into actual practice. This paper examines one particular pendulum problem and its implementation and use in a laboratory setting.
Background

The vibration lab is intended to provide students with an introduction to the theory of mechanical vibrations, and the practice of identifying and measuring vibrations in actual systems.

Vibration theory covered in this lab begins with the basic lumped parameters used to model simple mechanical systems: mass, damping, and structural stiffness. These building blocks are used to construct single degree of freedom (SDOF) analytical models of mechanical systems, which may then be used to predict vibration characteristics such as natural frequency.

Vibration practice in the laboratory involves instrumenting an actual system and determining actual vibration characteristics (e.g. natural frequency.) In addition to learning how to use transducers and data acquisition systems to collect and analyze vibration data, the student will (1) gain experience and confidence in the use of simple models, and (more importantly) (2) gain experience in discovering the source and magnitude of discrepancies between ideal analytical models and actual physical systems.

Students spend a great deal of time developing and using analytical models during the course of their undergraduate curriculum. A lab class can provide a valuable reminder of the limitations and approximations inherent in these analytical models.

Illustrative Example

A typical textbook problem taken from Steidel [1] is shown in Figure 1 below:

Figure 1: Problem 2.31 from Steidel
Solving this textbook problem provides an excellent application of vibration fundamentals. The student constructs a free body diagram of a lumped parameter model of this system (Figure 2 below), then performs a torque balance to develop the system model:

\[ J \ddot{\theta} + K a^2 \theta = 0 \]
\[ Mb^2 \ddot{\theta} + Ka^2 \theta = 0 \]

Figure 2: Free Body Diagram

This model can then be used to calculate the (ideal) natural frequency of the system:

\[ w_n^2 = \frac{a^2}{b^2} \times \frac{K}{M} \text{ rad}^2/\text{sec}^2 \quad (1) \]

This simple analytical model is based on the assumption that (1) friction is insignificant, and (2) distributed quantities such as mass and compliance may be treated as lumped parameters. Theory can be connected to the real world using a physical implementation of this SDOF pendulum.

**Pendulum Construction**

The pendulum of Figures 1 and 2 is constructed from a (modified) 12-inch steel utility square (Figure 3 below).
An adjustable weight is mounted on the top of the square, and its horizontal position can be adjusted by sliding it into place and locking it down with a set screw. The adjustable weight assembly is shown below in Figure 4. The top of the weight assembly is drilled and tapped to accommodate an accelerometer.
A hole to receive the axle is shown at the junction of the long and short legs of the L-Square (Figure 3), and a hole to accommodate spring(s) is shown at the tapered end of the short leg. A photo of the pendulum and its support plate is shown in Figure 5 below.

![Figure 5: Physical Pendulum, Axle and Support Plate](image)

The support plate serves two purposes. First, it supports the axle on which the pendulum oscillates (Figure 5, Figure 6B). Second, it allows a potentiometer to be attached to the pendulum axle for measuring and recording angular position. This is shown in Figure 6A below.

![Figure 6A: Mounting the Potentiometer](image)  ![Figure 6B: Supporting the Pendulum Axle](image)
The support plate assembly is fixed to ground by providing it with T-bolts which attach to a T-Slot baseplate, shown in Figure 7 below. The aluminum baseplate supplies a reaction mass to the oscillating pendulum.

![Figure 7: T-Slot Base Plate (Rendering)](image)

Adding mill feet to the angle bracket allows the pendulum to be positioned along the double T-Track arrangement, as shown in Figure 7. Once positioned with the pendulum centered over the central T-Slot, the pendulum assembly is locked in place using T-bolts and cam clamps. The single T-Track down the center is used to accommodate a similar adjustable bracket and spring. The spring is attached to the short leg of the pendulum and tensioned by sliding the spring bracket along the single track and clamping it in place. Once the long leg of the pendulum is lifted parallel to the surface of the baseplate, the spring is clamped in place and the pendulum is free to oscillate about its static equilibrium position.
Given an initial displacement, the pendulum will oscillate at its natural frequency. The potentiometer will record the angular position as a function of time, and both the damping ratio $\zeta$ and the damped natural frequency $\omega_D$, may be calculated from the data.

**Theory and Practice**

There are always discrepancies between idealized analytical models and actual physical systems, and engineering students must learn to reconcile these discrepancies. On paper the natural frequency of the pendulum system shown in Figure 1 is calculated as 36 rad/sec (5.7 Hz). In fact, the measured frequency is 33.4 rad/sec (5.3 Hz). The student is therefore faced with important questions that don't typically come up in a textbook problem but do typically come up in engineering practice: questions such as:

- Is the discrepancy significant?
- Can it be accounted for by the simplifying assumptions that were made in the calculation?
- Can it be accounted for in the measurement of the system parameters (K and M, as well as lengths a and b)? Would an uncertainty analysis be helpful at this point? (yes!)
- How accurate is the lumped parameter idealization of a distributed system?
- Is friction significant or may it be neglected (undamped versus damped natural frequency)?
- Where could error enter in to the measurement process?
- Where could error enter in to the data reduction process?

All of these questions prompt students to reflect more deeply on the analytical model as well as the measurement process and its limitations. This is the value of a laboratory associated with a lecture-type class: it keeps the theory grounded in reality.

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Example: Rethinking the Model

In reviewing the development of equation (1), most students immediately identified the assumption of a massless L-Square as a simplification they could easily eliminate. Several proposals were put forward for determining the rotary inertia of the L-Square and its effect on the natural frequency. The rotary inertia of this "massless" component could be determined:

- analytically - by hand
- analytically - using a computer
- experimentally

The hand calculation of an ideal L-shape is very straightforward, but once again an idealization creeps in. The actual shape of the pendulum is a modified L, with drilled holes and tapered edges. Accounting for these modifications becomes tedious - much more suited to computer calculation.

Using standard engineering software such as Pro/Engineer®, SolidWorks® or Inventor®, students can draft the L-Square and then list its properties, as shown in Figure 8 below. (This was in fact a post-lab exercise.)

The rotary inertia of the pendulum could also be determined experimentally using a trifilar suspension to measure the inertia. Trifilar suspensions were covered in an earlier lab, and dovetailed nicely with the current lab. By happy coincidence this earlier lab included measuring the rotary inertia of the L-Square. The experimental results were corroborated by the computer model and the result used to correct the estimate of the (ideal) natural frequency.
Conclusion

The textbook problem in Figure 1 provided an excellent exercise for learning and reinforcing basic vibration concepts: simple harmonic motion, natural frequency, construction and use of lumped parameter system models. Connecting the textbook problem to an actual physical system raised many interesting and practical questions. These questions in turn motivated further investigation and a deeper understanding of vibration theory.

The T-Slot baseplate and fixturing facilitates the development and use of other single degree of freedom pendulum geometries. Sample problems (again taken from [1]) and future pendula are shown in the Figure 9 below.

Figure 9: Other Pendulum Geometries (ref. [1])

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References

Dynamic Signal Analyzer Developed With LabVIEW-RF Tools

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Introduction
Signal distortion consists of changes in the original amplitude, frequency, or phase of a signal. Some of the functions of a Dynamic Signal Analyzer were implemented in a LabVIEW program which controls a NI Signal Analyzer.

Laboratory Equipment
Two sets of National Instruments LabVIEW-controlled RF systems are shown in Figure 1.

Figure 1. Two NI RF Systems

Each system has a signal generator (Figure 2) and a signal analyzer (Figure 3) and a second digitizer. These are housed in the NI PXI-1045 chassis.

Figure 2. NI PXI-5671 2.7 GHz RF Vector Signal Generator with Digital Upconversion
Dynamic Signal Analyzer

The main function of Dynamic signal analyzer is to transform the data from time domain to frequency domain. Frequency domain conversion cannot be done on continuous signals since they are not sampled and digitized. The block diagram of the DSA is shown below in Figure 4.

In general the goal was to add features and capabilities to the existing NI Advanced Harmonic Signal Analyzer program as provided by National Instruments.

Initial Work

The initial work involved determining the features to be developed and included in the final design. The measurement capabilities of Distortion Analyzer, Agilent 35670A, were studied and considered for inclusion in the LabVIEW-based design. Some of the capabilities were provided by National Instruments in the Advanced Harmonic Signal Analyzer demonstration program. The features of the Agilent equipment and the demonstration program are included in Table 1 below along with a plan for including selected features.

Added Features

Within the time period available for this project only few of the features (mentioned as DEVELOPED in Table.1) could be added. In Table 1,

- DEVELOPED: the features which were added to the new design,
- YES: the feature is already present and
- FUTURE: the feature that can be added in the future.

<table>
<thead>
<tr>
<th>Existing Measurements in Agilent 35670A</th>
<th>Existing Measurements in the NI Advanced Harmonic</th>
<th>Measurements Developed/Improved</th>
</tr>
</thead>
</table>

Figure 3. NI PXI-5661 2.7 GHz RF Vector Signal Analyzer with Digital Downconversion

![Block Diagram of Dynamic Signal Analyzer](image-url)
<table>
<thead>
<tr>
<th>Feature</th>
<th>Analyzer Measurement.vi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency domain</td>
<td>NO</td>
</tr>
<tr>
<td>Frequency response</td>
<td></td>
</tr>
<tr>
<td>Power spectrum</td>
<td>NO</td>
</tr>
<tr>
<td>Frequency spectrum</td>
<td></td>
</tr>
<tr>
<td>Coherence</td>
<td></td>
</tr>
<tr>
<td>Cross spectrum</td>
<td>NO</td>
</tr>
<tr>
<td>Power spectral density</td>
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<tr>
<td>Time domain</td>
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<tr>
<td>Time waveform</td>
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</tr>
<tr>
<td>Auto-correlation</td>
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</tr>
<tr>
<td>Cross-correlation</td>
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</tr>
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<td>Orbit diagram</td>
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<td>Amplitude domain</td>
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</tr>
<tr>
<td>Cumulative distribution function (CDF)</td>
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</tr>
<tr>
<td>Histogram</td>
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<tr>
<td>PDF</td>
<td>NO</td>
</tr>
</tbody>
</table>

Table 1. Project Plan and Prospects

**Stage 1:** In this stage, the NI Single Tone Generation vi was removed from within the NI demo vi. The output from this program was applied as input to the remaining Advanced Harmonic Signal Analyzer vi.
Stage 2: In this stage Signal Tone Generator blocks have been replaced with NI_RFSA blocks to collect input signal from external source and implementation of Dynamic Signal Analyzer. Single Tone Generator was able to generate a single tone but the input signal was generated internally. This program was not able to collect the signal generated by an external source. In this project, RFSA down converter (NI-PXI-5600) was used as the signal source. To collect this external signal generated on to the PC and further processing, the Single Tone block has been replaced with the RFSA blocks.

Fundamental frequency is the lowest frequency in the harmonic series. Any device producing a fundamental frequency also produces harmonic frequencies that are multiples of fundamental
frequency. All the harmonic frequencies are lower in level compared to the fundamental frequency. While measuring Total Harmonic Distortion of an amplifier, the extent of distortion is the measure of the level of harmonics at the input to the level of harmonics at the output.

Stage 3: In this stage, different features were developed and added to the Dynamic Signal Analyzer vi. NI_RFSA blocks take the signal from any signal generator and processes through different stages of signal acquisition and signal processing. Output of NI_RFSA blocks is given to the Harmonic Distortion Analyzer which performs the harmonic analysis on the signal and Total Harmonic Distortion of the signal is determined.

Below figure shows the expected outputs for the features added.
Conclusion
To conclude on the whole, general purpose Dynamic Signal Analyzer vi which can take signal from an external signal device has been developed and has been successfully implemented using LabVIEW. The future developments that can be done on this design have been mentioned in Table.1.

The authors would like to thank Dr. William Hudson, ECET Department Chair, for his efforts to help improve the communications laboratory and for his ongoing encouragement and support of students and faculty. Also the staff of National Instruments provided valuable guidance on operation of the RF instruments and LabVIEW programming.

- Minnesota Center for Excellence in Engineering & Manufacturing and National Instruments for supporting acquisition of the NI RF equipment.

References
Enhancing the Design Experience by Developing Projects for Special Needs Children

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ABSTRACT
This paper describes how projects for special needs children enhance the design experience while providing a valued service to the special needs children. Teams of students in the Mechanical Systems Design course at the University of Wisconsin-Platteville (UWP) worked closely with the occupational and physical therapists from the Platteville K-12 school system to design various adaptive devices for children with special needs. Seventeen adaptive devices were designed and built in the past two semesters. This paper includes descriptions of three of these: a redesign of a bicycle for a child with cerebral palsy, a learning center for a child with spina bifida, and a visual light activity box for a child recovering from pilocystic astrocytoma brain tumors. The learning center project was a continuation of a similar project from the previous semester. Some of the specific benefits of these projects to the children include: building of self esteem and confidence, providing an improved learning environment, and redeveloping of motor skills. A formal design process as described in this paper was used to determine the final design for each team. A prototype was then built and the projects were presented to an audience of parents and friends of the special needs students, the therapists and the course instructor. The prototypes shown in this paper have been successfully used by the children at school for the past semester.

INTRODUCTION (DEFINING THE PROJECTS)
This paper describes three special needs projects that students designed and built this past semester at UWP. These projects demonstrate the design process and how they have enhanced the design experience. Initial discussion took place between the occupational and physical therapists and the instructor of the Mechanical Systems Design course to create a need for projects that could be designed and built in one semester for special needs children in the school system. The projects were then presented by the therapists to the students with explanations of the children’s disabilities. These adaptive-type devices would have to motivate the children to use the devices and benefit the children by enhancing their self confidence. Upon use of the devices, the children should also improve in the following typical ways: improving motor skills and self-esteem for the child with cerebral palsy, assisting in placement of learning materials for the child with spina bifida, and recovering lost motor skills for the child recovering from brain tumor surgery.

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**METHOD OF SOLUTION – FORMAL DESIGN PROCESS**

Teams composed of four to six students were created to match up their interests as best possible. The student individual teams then met with the special needs child, along with the therapists and classroom instructor. At this meeting, the special needs children, with insight provide by the therapists, demonstrated their abilities and needs.

**Need Statement or Problem Definition**

Based on a standard design process, a formal need statement was developed by each team. The need statements for the projects described in this paper were as follows:

- There is a need to redesign and modify a bicycle adaptable to a child with cerebral palsy so the child can participate with other bicycle riders.
- There is a need to design and build a learning center to allow a student with spina bifida to participate in the classroom learning experience.
- There is a need for a device to stimulate a student’s eye-hand coordination to regain their normal use of upper body motion skills.

A Gantt chart was then created to assist in planning and scheduling of the project.

**Background Information**

Based on the defined need and information gathered during the initial visit with the special needs child, the teams then obtained background information on the particular disability of the child and began searching for existing devices that might meet the need.

**Problem Constraints**

Through information from their background research, from suggestions made by the therapists, and based on observed motor skill behavior and gathered physical data of the children, the teams then identified problem constraints or task specifications. Some significant constraints for the projects included:

- For the redesigned bicycle:
  The bicycle must be ergonomically designed and modified to account for the special needs of the child, including an adjustable seat with supporting back, adjustable pedals with straps, and adjustable handlebars (actually reversed from normal position) all to make sure the bicycle is safe and stable to ride.

- For the learning center:
  The learning center must have easily adjustable moving parts. The center must have sufficient supporting arms to hold books, notebooks, and computer.

- For the visual light activity box:
  The visual light activity box must have proper dimensions to be transportable. The orientation of the peg/light holes must be laid out to cover a sufficient area to increase the student’s peripheral vision, but not be spread out too far to cause the student to over-reach.
Possible Solutions

Possible or candidate solutions were generated with each team required to generate two to three possible solution concepts. These concepts were then evaluated based on various weighted criteria in a decision matrix often including such criteria as ease of assembly, product functionality, ease of use, safety, quality, and cost. Decisions on material selection and manufacturing process, sometimes dictated by the client, also were of significant importance in the design process. These concepts were presented to the therapists. Often concepts were demonstrated using rough models of wood or cardboard or CAD animations, as appropriate. The final design decision was based on numerous iterations with input from the therapists. A typical decision matrix for the learning center is shown in Figure 1.

<table>
<thead>
<tr>
<th>Weight Factor</th>
<th>Score</th>
<th>Value</th>
<th>Score</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to Produce</td>
<td>0.05</td>
<td>10</td>
<td>0.5</td>
<td>5</td>
</tr>
<tr>
<td>Reliability</td>
<td>0.2</td>
<td>10</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Material cost</td>
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<td>8</td>
<td>0.8</td>
<td>6</td>
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<tr>
<td>Manufacturing cost</td>
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<td>Low complexity</td>
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<tr>
<td>Ease of Assembly</td>
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<td>10</td>
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<tr>
<td>Ease of adjustability</td>
<td>0.2</td>
<td>9</td>
<td>1.8</td>
<td>7</td>
</tr>
<tr>
<td>Ease of maintenance</td>
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<td>9</td>
<td>1.8</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>9.30</td>
<td>7.25</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1 – Typical decision matrix for learning center for special needs child

Proposed Solution

The final design concept was then selected consistent with the best scored possible solution. This solution was detailed with the aid of computer-aided software. Appropriate engineering principles and equations were included to validate the soundness of the designs. A prototype was then built by each design team. The final prototypes of the three designs described in this paper are shown in Figure 2. These prototypes, along with an oral presentation and a written engineering report were presented to the therapists. The oral presentation was also attended by the parents and relatives of the special needs child, and other interested parties from the university, including the Associate Dean, and Chair of the Mechanical Engineering Program.
ENHANCEMENT OF DESIGN EXPERIENCE

From these projects for special needs children, we observe how the design experience for the students has been enhanced as follows:

- Solve real life problems with a sponsor or client.
- Introduce, interact, and serve students with special needs.
- Design unique and challenging projects for special needs.
- Provide a needed device at an affordable price.
- Increase student’s enthusiasm.
- Enhance team working skills.
- Enhance communication skills.

It is emphasized that the same design process is used for special needs devices as with developing products used by the general public. Projects incorporate design considerations, such as scheduling, project management, and team working skills, working within interdisciplinary settings, working with vendors and creating a bill of materials, safety, ergonomics, aesthetics, societal concerns, liability, and cost.

CHALLENGES AND RECOMMENDATIONS

Some challenges working with special needs projects include:

- Expectations that a working useful device will be created that is aesthetically pleasing;
- Variability of degree of difficulty in projects;
- That the device will be built and delivered at the assigned end of semester time;
- Follow-up logistics to observe if the actual criteria have been met;
- Lack of assurance to modify or have continuity to improve on a project from one semester to another to meet client recommendations, (In the case of the learning center, numerous changes were made by encouraging feedback to suggest improvements from one semester to the next. These changes resulted in an excellent professional functioning working solution for the high school student using the learning

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center. Fortunately, the course has been taught in continuous semesters and by the same instructor for the past two years to make this possible.) Recommendations include ways to ensure follow-up of the projects to observe if they are meeting the needs of the special needs children and continuity in course teaching and its requirements so that improvements can be made to previous projects as necessary.

ACKNOWLEDGMENT
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BIOGRAPHY
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Dance + Engineering:  
A Collaboration for Freshmen Engineering Design Students

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ABSTRACT
This paper examines a collaboration between the freshmen-level engineering graphics and design class at the University of St. Thomas (UST), dance students at Macalester College and the University of St. Thomas, Ordway Center for the Performing Arts, and Diavolo Dance Theater. Traditionally, students in ENGR171 completed a design project for a fictitious client. Through this collaboration, however, the students were given a real client, a more open-ended initial design brief, and a strict timeline. The engineering students participated in a movement workshop to familiarize themselves with some of the methods the dancers would be using. Additionally, they met with their clients to establish user needs and engineering specifications for the project. Students’ designs were then commented on, via the internet, by dancers, set designers, potential users of the set piece, and potential manufacturers of the set piece. The students’ deliverables included written descriptions of their designs, CAD models, and oral presentations. This paper will address some of the strengths and weaknesses of this collaborative project, as well as lessons learned that can be applied to future collaborative projects.

INTRODUCTION
Engineering Graphics and Design (ENGR171) is a four-credit required course in the Mechanical Engineering major. It is typically taken during fall or spring semester of the freshman year and is usually the first or second course the student takes in the engineering department. The other engineering course that electrical and mechanical engineering students take during the freshman year is a one-credit Introduction to Engineering course. The following is the ENGR171 course description as written in University of St. Thomas’ course catalog:

“Through a combination of lectures, hands-on computer lab time, and design projects, students will learn to read, and create, engineering drawings and use computer-aided-design (CAD) terminology and technology. Topics covered will include the engineering design process, rapid prototyping, principles of projection, and introductory methods of representation and constructive geometry.”

Historically, this course has focused on drafting and CAD, (Hennessey 2002, 2005), though in the past two years, St. Thomas faculty has added an emphasis on design process, product design, and rapid prototyping. In addition to a final project in which students take apart a complex object and create, using the SolidWorks CAD program, a full packet of engineering drawings and models for the object, students must complete two design projects during the semester. In a typical semester, these projects are:
• Project 1: “Chair Design” Students must design a chair for a specified imaginary client that can be built using a single piece of standard plywood. After creating a CAD model of this chair, students are taught how to use a laser cutter to make scale models of the chair.

• Project 2: “Chess Project” Students must design a chess set for their choice of one of three possible imaginary clients (a blind individual, a child, or a beginner chess player.) They must create a list of user needs for the chess set, and then create a CAD model of a full set of chess pieces that meet these needs. Students are then given the opportunity to have one of their designed pieces 3D printed in the design lab.

The goal of these projects is to encourage students to apply a structured design process to an open-ended design challenge.

In the spring of 2009, the lead instructor for ENGR171 was approached by representatives from Ordway Center for the Performing Arts as part of their Campus Connections program. The Campus Connections program (funded by The Wallace Foundation) is a campus-wide partnership with Ordway Center designed to build bridges between the Ordway and communities of students, faculty, staff, and alumni. The program’s goal is to develop effective ideas and practices to integrate arts-based methodologies into teaching practice, as well as to build current and future audiences and enhance participation in the arts. As part of this program, the Ordway was interested in exploring cross-curricular connections to the presentations within their World Music and Dance Series. Introducing the engineering students to dance through work with Los Angeles-based Diavolo Dance Theater, seemed logical because of the company’s reliance on objects as central to its aesthetic, and, further, would allow for students focused in two very different disciplines (science-based and arts-based) to form a practical working relationship based on mutual creativity.

Engineering is a natural fit with a Diavolo project as their dance style is very physical and always involves the use of an object or set piece. In their artistic statement, the importance of set pieces is stressed: “Architectural structures or sculpted adaptations of everyday items - sofas, doors, stairs - provide the backdrop for dramatic and risky movement, revealing metaphors for the challenge of maintaining human relationships in modern environments” (Heim). During a collaborative planning process with team leaders from UST’s Engineering Department, Macalester’s Dance Department, and Ordway’s Community Engagement department, a process emerged in which UST Engineering students, Macalester and UST student lead dancers, and dancers from both schools would be actively and collaboratively engaged to work with Diavolo in the creation and presentation of an original dance piece, to be performed during the Spring 2010 Macalester Dance Concert. All students would work with the Diavolo team to learn the company’s specific aesthetic and would apply skills from their own disciplines to the final project. A set piece would be created and Diavolo company members would guide the Macalester and UST dancers through the process of choreographing a dance around the constructed set piece. Thus, for the Spring 2010 semester, Project 1 (the chair project described above) would be replaced with an involved project in which the students would design a set piece to be the central physical element in a dance performed during the Macalester Spring 2010 Dance Concert.
It was decided that students from ENGR171 would individually design and model (using SolidWorks), a set piece based on design requirements and feedback given to them by members of Diavolo and the student lead dancers from Macalester and UST. Members of Diavolo, the student lead dancers, and representatives of the Ordway would discuss the proposed designs and then select one to be constructed. A build team from the University of St. Thomas would then create the physical set piece based on the selected design. This set piece would then be delivered to the Ordway for the intensive rehearsals between Diavolo members and Macalester/UST dancers, during which a dance involving the set piece would be choreographed. Below, this process will be discussed in detail.

PROJECT LAUNCH
One challenge presented by this project was the timeline. Typically, the first design project for ENGR171 would be presented approximately at the end of the fifth week of the semester. However, in order to have a set piece delivered to the Ordway in time for the intensive rehearsals with Diavolo and the Macalester/UST dancers, the first project was launched at the beginning of the fourth week of the semester. On the Monday of the fourth week of the semester, Jacques Heim, Artistic Director of Diavolo, along with Garrett Wolf, veteran Diavolo company member, joined the ENGR171 students for the project launch.

During the initial launch, the Diavolo representatives showed video footage of their performances and discussed the aesthetic of Diavolo. Students were then given the following project description:

For this project we are partnering with Ordway Center for the Performing Arts, dancers from Macalester College and the University of St. Thomas, and Diavolo Dance Theater of Los Angeles. A group of dancers will be training with Diavolo company members in order to create and perform a piece in the style of Diavolo. That’s where you come in! Diavolo dances use props and/or set pieces. Using your knowledge of the design process and SolidWorks, you are going to design a piece for the Macalester/UST dancers. To do this, we will be working with dancers from both Macalester/UST and Diavolo. One of you will have your design chosen to be built into a set piece in which a dance will be choreographed around. Your set piece must be able to be built out of one to three pieces of plywood, 8’ x 4’ x 1/16”. Your design must not require the use of any fasteners, with the exception of fasteners made out of the plywood itself. (Note that if your design is chosen for construction, we will work with you to design supports for it which may include the use of additional wood and/or fasteners.) We will then be building 1/12 scale models using thin plywood and the UST Design Lab’s laser cutter. As you work on this project, please reflect on the lectures, readings, discussions of the engineering design process that we had at the beginning of the semester!

The requirements for the project’s deliverables were also presented to the students at this time. There were two sets of deliverables for this project, as described below. Students were given a chance to ask questions of the Diavolo representatives.
The next class session consisted of a movement workshop for the engineering students led by Jacques Heim and Garrett Wolf of Diavolo. Creative thinking was emphasized throughout the workshop and students were encouraged to use trust in order to accomplish the movement exercises, which included leaping into fellow classmates’ arms during the Diavolo "Superman" exercise. The engineering students were also given a short assignment to choreograph a series of movements on a folding chair, which helped them gain insight into the dancers' role of moving and choreographing on a set piece.

PROJECT DELIVERABLES
The following are the instructions that the students received for the first deliverable set. Please note: Blackboard is an online forum used by UST for class discussions and postings.

**Part A: Preliminary designs** [due 10 days after the project launch]

*Please post the following on Blackboard by noon. Note that there is a scanner available for your use in OSS 105 [engineering student lounge].*

- A half-to-full page write-up explaining your design, and why you think it is appropriate for the Macalester and UST dancers, based on your discussions and work with Diavolo.
- 1-2 pages of sketches (hand drawn) showing your design in enough detail to give the viewer an idea of the finished piece. You will be receiving feedback on these drawings from the dancers and choreographers.

The students were encouraged to be bold in their ideas, and to focus on hand sketches and written descriptions which would give the viewer a sense of what the design would look like when completed, with enough information and detail such that constructive criticism could be given. During the first few weeks of ENGR171, students are given instruction in various hand-sketching methods. The sketching part of this project is meant to encourage students to continue practicing their drawing skills. Students were able to get feedback from dancers and choreographers of Diavolo, staff members from Ordway Center for the Performing Arts, the lab and lecture instructors from ENGR171, the student lead dancers, and the shop manager from the University of St. Thomas, who would lead the build team for the set piece, using an on-line discussion board format. Samples of two of the hand-drawn sketches, minus the accompanying write-up, can be found in Figure 1.

![Samples of the initial sketch phase of the design project.](Work by Aisha Adam and Dimitri Angelo)

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Following this on-line exchange of ideas, along with accompanying discussion in the ENGR171 lecture and lab, students proceeded to Part B of the project.

**Part B: Presentation, models and drawings of your final design** [due 18 days after the project launch, 8 days after the completion of Part A]

Create a new folder, entitled “Project 2,” in your ENGR171 directory. In this directory, include:

- SolidWorks models of each part for your final design. (Parts should be fully dimensioned for the actual size of the piece.)
- An assembly file for the completed piece
- (A) SolidWorks drawing file(s), saved in a .dwg format, to use as a cutting file
  - 8” by 4” page for each sheet of plywood that you are using
  - No border or title block
  - Front views only of each piece, laid out however you intend for them to be cut from the wood at 1:12 scale
  - Note that this is not an engineering drawing, but rather the cutting template for the laser cutter. We will be using this file to produce your wooden model.
- Please submit a packet containing the following:
  - One page describing your final design. What was the idea behind it? How did your design change based on feedback? What do you think some of the challenges would be if we decided to build this full scale for the Macalester dancers?
  - Printouts of the SolidWorks model (assembly) of your piece
  - A printout of the SolidWorks drawing(s) described above
  - An 8.5x11 inch poster designed using PowerPoint which shows:
    - An assembly drawing of your design
    - A short description of your design
    - A title for your design
    - Your name and class information (ENGR171 Spring 2010)
    - Any images or sketches which you think help explain your design

In class you will have 60 seconds to give a short presentation on your design, with the poster projected on the screen as a visual aid. The lead student dancers and Ordway staff, in addition to your classmates, will be there. The final design will be chosen after these presentations.

Samples of student posters can be found in Figure 2. A sample of a student’s SolidWorks assembly and corresponding laser cutter file can be found in Figure 3.

**DESIGN SELECTION**

Eighteen days after the project launch, the students gave their 60-second (single PowerPoint slide) presentations showing their designs. Samples of these slides can be found in Figure 2. In the audience for these presentations were the ENGR171 faculty and students, the student lead dancers, and representatives from Ordway Center for the Performing Arts. Representatives from Diavolo were not present due to their travel schedule. During the presentation, individuals
involved in choosing the final design to be constructed for the Macalester dance took notes on
which designs seemed most promising. After the mini-presentations (which took one full class
period), the ENGR171 instructor met with the student dance leads and the Community Events
Coordinator from the Ordway to choose the final design. Based on the results of this meeting, a
short list of approximately five of the most promising designs were emailed to Jacques Heim,
Artistic Director of Diavolo, who then joined the group by phone. In the course of the discussion
with Jacques Heim, the final design was chosen. As will be discussed below, the group chose
the final design based on a variety of factors, including how well the design would work for a
group of 20 dancers.

Figure 2: Samples of student slides for the 60 second project pitch presentations. The slide on the left represents the design that was ultimately chosen for construction. (Work by Tom Flake and Samantha Stewart)

Figure 3: A sample of a student’s SolidWorks assembly file and one of two corresponding laser cutting templates that are associated with this assembly. (Work by Matthew Hanson)
PROJECT BUILD
Three students who had previously taken ENGR 171 were hired to work with the School of Engineering lab manager to build props based on the design provided by the student. It is important to note that the design which was built was true to the concept designed by the student, but not the physical design. One challenge of this project was that ENGR171 has no prerequisites, and thus the students did not necessarily have any experience with physics or manufacturing. The build team worked with the ENGR171 instructor as well as the student designer to revise the design to one that would be sturdy and buildable (Figure 4).

Figure 4: Undergraduate engineering students constructing the final set piece for the Macalester and UST dancers. (Photographs courtesy of John Angeli)

Figure 5: Student Tom Flake with the set piece created using his design.

While only one design was built at full scale (see Figure 5), every student who submitted a laser cutting file (as described in the instructions for Part B of the project and pictured in Figure 3) had their parts cut on a laser cutter. Some of these scale models can be seen in Figure 6. The final build involved creating two sets of the chosen design (thus using double the material limit that was specified in the instructions). This was done at the request of the Diavolo members.
SOCIAL COMPONENT
Students had the unique opportunity to attend a performance by Diavolo at Ordway Center for the Performing Arts a few weeks after the final design presentations. Prior to the show the ENGR171 students socialized with the Macalester and UST dancers, Diavolo members, and staff of the Ordway. The chance to socialize with others involved in the project strengthened the sense of community related to this project. Watching Diavolo perform with large set-pieces on stage also gave the engineering students the chance to see commissioned design works in use, giving a “real-life” factor to the project.

STUDENT FEEDBACK
As part of the Ordway’s Campus Connections program, a facilitator from the Ordway ran a tuning session with the students the day after the optional visit to the Diavolo performance (approximately two weeks after the “winning” design was chosen). Each student was given a chance to verbally share their warm feedback about the project as well as their cool feedback, in the form of “I wonder…” statements. Both sets of feedback were helpful in pointing out what worked well, what could have been done differently, and further ideas for the project if done again.

In the warm feedback section of the tuning, the following were some of the aspects that the students thought were most successful about this project:

- Having the actual client (the student lead dancers, the Diavolo Artistic Director and a Diavolo company member) at the project launch meeting was very helpful.
- The online critiques of the preliminary designs were found to be helpful. At least one student discussed how this feedback led him to change his design between the initial sketch stage and the final model stage.
- The chance to build a relationship with the client was a positive experience – having the opportunity to work with an actual client who would use the design (not just a hypothetical assignment).
- The movement workshop with Diavolo was helpful. The engineering students noted that this helped them think about movement possibilities, and also that such an experience was fun since it was something that an engineering student wouldn’t normally get the chance to do (“able to experience instead of just watching”).
- Many students mentioned that having the chance to design something “real” as freshmen was very exciting for them. As one student said, “What was designed was actually going to be built – made it real – the design has a ‘life.’”
• Competition between designers was seen by the students to be a positive aspect in that it encouraged them to produce creative, original designs.
• Learning about dance as well as working with Diavolo and learning their aesthetic style helped the students design.
• Students appreciated the chance to meet many different people from different fields.
• The project taught students about collaboration and incorporating many crucial points of view, which is important for arts-integration work.

Anecdotally, students seemed much more engaged with this project than they typically have been when completing the chair project (described above) in previous semesters. Based on the warm feedback, it seems that the key factors in the students’ involvement are likely the participation of a real client who was available to give students feedback, and the knowledge that their work may be turned into a physical object used by the client.

During the cool feedback portion, students were all invited to talk about things that may have been done differently. Below is a sampling of this feedback. In italics below each suggestion, we have included a response to explain the rationale behind our choice:

• I wonder if next time, there could be no material constraint – instead, have a budget to allow for more creativity?  
  *For this project, we constrained the materials so that the build team could begin construction of the set as soon as a design was chosen and complete it in a timely manner (the build team had only one week to build the set before intensive rehearsals for the dancers began). Additionally, as this project was done early in the semester, the engineering students had limited knowledge of SolidWorks. By constraining the project to plywood, we ensured that students would be able to create a design using simple sketching and extrude tools in SolidWorks.*

• I wonder if the project could happen at a different point during the semester? 
  *Some students felt ill-prepared for doing a design project this early in the semester, given the limits of their SolidWorks experience. Given the deadline for delivering the set piece, we could not push this project back any further in the semester.*

• I wonder if we could have more time together to talk about design, an important part of the collaboration, and to talk about the final product? 
  *Again, due to the need for the dancers to have the finished set piece by the middle of the semester, we were constrained to a tight timeline.*

• I wonder what would happen if we worked in teams rather than individually, allowing us to exchange ideas and possibly develop more creative designs? 
  *This is a good point and one that we struggle with whenever we design ENGR171 projects. Since this is one of the first college classes the students take, we like them to do a mix of individual and group projects to strengthen their technical skills, as well as their teamwork abilities. The final ENGR171 project is always done in teams.*

CONCLUSION

From an instructor’s standpoint there were a few unique challenges and benefits that came from this project. First and foremost, when collaborating with the many partners involved in this
project, the ENGR171 instructor lost a level of control over the class project. Flexibility was key.
Because the students were freshmen, many of whom had no college-level physics classes, the students did not have the skills to do static and dynamic analysis of their designs. In some ways this project could be considered a concept design project as opposed to an engineering design project. Were this class populated with students who were further along in their engineering studies, force analysis could be added to the project. Additionally, the students’ knowledge of manufacturing methods was extremely limited, so the project organizers understood that the project build crew and ENGR171 instructor would have to redesign the chosen set piece to make it buildable. For the chosen design, this was indeed the case and the edges of the box, critical for attaching the sides together, were redesigned. Figure 7 shows the boxes in their final form, being used by the student dancers.

Figure 7: Student dancers choreographing on the chosen set piece.
(Photo courtesy of Amy Miller.)

The opportunity to have first year students working with real clients added a level of excitement to this course that is absent in cases where the projects involve fictitious clients. Their attention to the project’s requirements and user needs was stronger, likely owing to the fact that they were presenting their projects to the client and getting real feedback. While this particular project is unlikely to be repeated due to the unique nature of the opportunity, we will attempt to find other clients that ENGR171 students can work with in order to duplicate the success of this project.

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REFERENCES


BIOGRAPHICAL INFORMATION

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Bringing Engineering Concepts into the Kindergarten Classroom

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Abstract

This paper focuses on the K in the K-12 pipeline for engineering education. It will describe the experiences of the partnership of an engineering professor and elementary teacher in bringing engineering activities into a kindergarten classroom. It will discuss how the activities were adapted for the kindergarten level and will provide suggestions on how to integrate them into a school district’s required curriculum. Benefits for the kindergarten teacher as well as the engineering professor will also be discussed.

1. Introduction

Kindergarten is a transitional stage in a child’s life. Their young minds are soaking in new ideas and learning every day. The kindergarten curriculum not only focuses on their social and emotional development, but it also emphasizes the importance of academics such as reading, math, science and problem solving. Bringing fun, hands-on activities into the classroom that demonstrate simple engineering concepts is an excellent opportunity to introduce these students to engineering at a young age and motivate their interest in learning. There are numerous resources available for teachers through websites such as pbskids.org and www.pbs.org/teachers for engineering activities. Teachers could use these resources in the classroom on their own; however, a partnership with engineering faculty or engineering student groups make it both exciting for the kindergarten students and more feasible for the teacher to fit such activities into the curriculum.

This past year, the partnership between a kindergarten teacher and engineering professor enabled bringing hands-on activities that demonstrate basic engineering concepts into a kindergarten classroom. By combining the school district’s Everyday Mathematics curriculum with real-life engineering applications, the students received a deeper understanding of how math and science can relate to their everyday lives. The activities were adapted from Public Broadcasting Service (PBS) resources at www.pbs.org/teachers and modified to be appropriately challenging for the kindergarten level and to promote student engagement. The lessons encouraged the students to explore, question, predict and test their ideas through a hands-on, interactive focus. In each session, the students were enthusiastic, interested and eager to be involved.
In this paper, we will describe the activities used, how they were adapted for the kindergarten level and discuss what we learned regarding implementation strategies. We will summarize the results from basic survey questions answered by the kindergarteners following several of the activities. Suggestions for how these activities can be integrated into a school district’s required curriculum will be discussed. Benefits for the kindergartener teacher as well as the engineering professor will also be highlighted.

2. Engineering Activities

The activities were selected based on several criteria: (1) ability to demonstrate basic engineering concepts, (2) hands-on, interactive focus to engage students, and (3) fit a unit theme already being taught in the mathematics, science or reading kindergarten curriculum. The teacher rotates through different unit themes in reading, math and science throughout the school year. The activities were implemented in the spring of 2010 in a classroom of 19 kindergarten students at Hoover Elementary School in North Mankato, MN. Each activity consisted of two parts, a large group discussion or story and a small group, hands-on portion. The students performed the hands-on activity in groups of 4 – 5 students as they rotated through the afternoon math stations. The integration into the math stations format used in the kindergarten curriculum will be described further in Section 4. A description of each of the engineering activities is provided below.

2.1 Floating Objects

Unit Theme: Water (Science)
Engineering Concepts:
- Buoyancy

The whimsical Baby Einstein book entitled “What Floats?” by Julie Aigner-Clark and illustrated by Nadeem Zaidi was used to get the students thinking about things that float versus those that sink. The book ends with the line “It’s curious how a ship floats by as heavy as can be, while a pebble drops with a little plop and sinks beneath the sea.” After reading this book and “Curious George, The Boat Show” to the class, the engineering professor led the students in a large group discussion thinking of other objects that float or sink.

The small group activity gave the students the opportunity to play in the water and experiment with an assortment of objects. They started out with two objects that were the same size, shape and color but had significantly different weights, a golf ball and a ping pong ball. The students voted on if each ball would float or sink and then tested their hypothesis. Then, they were given a small plastic bowl, instructed to place the golf ball inside the bowl and asked if it would now float or sink. Some of the students were surprised that the golf ball that previously sank would float when the bowl and ball combination were placed in the water. They were even more surprised when they were able to load as many as 10 golf balls into the bowl before it began to sink. The students also experimented with cans of food, small wooden boards, plastic containers and rocks. The basic principles of buoyancy were explained while the students enjoyed playing with the objects in the water tub.
2.2 Levers

Unit Theme: Pan Balance (Mathematics)

Engineering Concepts:
- Simple machines
- Levers and fulcrums

Source:
- “Level Investigation” by Sid the Science Kid
  (http://www.pbs.org/parents/sid/activities.html?leverinvestigation)

In this activity, the small group portion was conducted first in the classroom. Following completion of the afternoon math stations, the entire class took a field trip outside to the playground for the large group part of the activity. The small group activity consisted of a crate filled with heavy books, a board 6 – 8 ft long and 12 – 16 in wide as the lever, and a small step stool placed underneath the board as the fulcrum. The large group activity required a door for demonstration purposes and a plastic spoon and several marshmallows for each student.

The small group activity was started by placing the crate filled with heavy books on the ground and giving each student the opportunity to try to lift the crate. Then the crate was placed on the end of the lever with the fulcrum positioned in the middle. Each student was again given the opportunity to push on the lever and feel how much easier it was to lift the crate. The students experimented with moving the fulcrum to different positions and the effect it had on the force required to push down on the lever and lift the crate. During the activity, the engineering professor discussed levers, fulcrums and how simple machines can be used to make tasks, such as lifting a heavy object, easier.

After each group had rotated through the lever investigation station, the class put on their coats and headed outside to the playground. On the way out, they stopped at the double doors exiting the school building and the engineering professor used the doors and a student volunteer to demonstrate a lever in action. The students saw how it is easier to open a door if you push or pull on it farther away from the hinges. This was a great opportunity to connect something they do multiple times a day to the engineering concept behind it. Outside, the students were each given a plastic spoon and several marshmallows. Using the spoon as a lever and their thumb and index finger grasping positioned on the spoon as the fulcrum, the students launched their marshmallows into the air. They experimented with how moving their fulcrum up and down the spoon handle affected how far the marshmallow was launched.

2.3 Sand Castles

Unit Theme: Ocean Animals (Reading)

Engineering Concepts:
- Cohesion and mixing materials to increase strength
- Structurally sound foundations for building

Source:
• “Day at the Beach” with Curious George
  (http://pbskids.org/curiousgeorge/games/day_at_beach/day_at_beach.html)

The book “Curious George Goes to the Beach” by H.A. Rey and Margaret Rey was used to introduce the Sand Castle activity. The engineering professor read the book to the class during circle time and then called on volunteers to discuss their explorations at the beach and previous experiences in building sand castles. The children were excited to talk about their experiences of playing in the sand box and at the beach.

The materials required for the small group activity included several large, shallow tubs of moist sand (approximately two students per tub) and sand shovels, cups and other molds. A large tarp spread out underneath the station area was helpful to capture the sand spillage and facilitate easy cleanup of the classroom following the activity. At the start of each small group rotation, the engineering professor used two smaller tubs, one with dry sand and the other with very wet sand, to demonstrate the importance of the right mixture of sand and water to get the proper consistency for building sand castles. Cohesion between the sand and water and how it increases the strength of the mixture was discussed.

The students used various sizes of cups and molds to build their own sand castles within the tub. As they played in the sand, the engineering professor discussed structurally sound foundations for building sand castles. Through demonstration followed by testing it on their own, the students learned about the need for a level building site and the importance of using larger molds for the bottom of their sand castle and smaller molds for the top.

2.4 Tower of Coins

Unit Theme: Money (Mathematics)

Engineering Concepts:
• Forces
• Friction
• Inertia

Source:
• “Tower of Coins” by Zoom
  (www.pbs.org/teachers/connect/resources/2692/preview/)

Most kindergartener’s are already familiar with the fun science stories of The Magic School Bus by Joanna Cole. This activity was introduced by the engineering professor reading “The Magic School Bus Plays Ball” by Joanna Cole and illustrated by Bruce Degen to the class. In this story, teacher Ms. Frizzle and her class take a Magic School Bus ride into a non-friction world. Through a baseball game played on a field without friction, the story explains forces and inertia. Since the students were already familiar with the characters in the Magic School Bus series, the story provided a fun and imaginative way to introduce these engineering concepts to the class.

At first glance, the unit theme for this activity may seem disconnected to forces, friction and inertia. The students had been learning about money over the past month. This engineering
activity integrated into the money theme by giving the students a fun, hands-on activity using coins. During the small group activity, each student was given a stack of 12 coins of the same size. Pennies, nickels, dimes and quarters were used for the different stacks. The students were asked to count how much money they had in their stack and as a group determine which student had the most money. They were also asked how many of their coins would they need to trade in for a $1 bill.

The small group activity was started using a ball at rest and rolling in a straight line to explain the basic concept of inertia and forces. Friction was demonstrated by the rolling ball eventually coming to a stop. A small box (filled with coins) on an inclined surface was used to further illustrate friction and its kindergarten level explanation as a “sticky” force. The engineering professor then demonstrated with one of the stacks of coins how pushing on the bottom coin slowly causes the whole stack to move together due to friction and how hitting the bottom coin quickly overcomes friction and causes just the bottom coin to shoot out and the stack to stay at rest. The students then experimented with their stack of coins. First they moved their stack of coins together by slowly pushing on the bottom coin. Then, they tried to get the bottom coin to shoot out and the rest of the coins to remain in the stack by hitting the bottom coin quickly with a flat utensil (e.g., metal spatula or butter knife). The activity took some practice for them to learn the right speed and force to use with the utensil and develop the skill to hit only the bottom coin. However, once they achieved it, they had fun with their new “magic trick”.

2.5 Wind Power Car

Unit Theme: Weather (Reading, Science)

Engineering Concepts:
- Forces, friction and inertia
- Wind power

Sources:
- “Balancing Balls on Air” by Zoom (pbskids.org/zoom/activities/phenom/balancingballsonair.html)

We started the activity with a large group demonstration. Volunteers were called on from the class to participate in the demonstration of a ping pong ball floating in the stream of moving air from an electric blower. The volunteers tipped the blower hose at different angles and the class was amazed at how the ball remained suspended in air. During the demonstration, the engineering professor discussed forces and the power of wind with the class.

Following the demonstration, the students completed the wind power car activity in small groups. They each built a small car using a 4x6-inch index card as the car body, drinking straws for axels, and LifeSavers® mint candies as wheels with mini marshmallows as stoppers to keep the wheels from falling off. They built sails using popsicle sticks and a choice of aluminum foil, plastic bags or small paper cups and added load to their cars using string with paper clips attached to the end.
Discussion points used in conversation with the small group during the activity included kindergarten level explanations of inertia, forces, friction and wind power. Basic demonstration of the car remaining at rest until the force of the wind acts upon it, the force of the wind needing to be stronger than the friction to get the car to move, and friction resisting the motion of the car and causing it to slowly stop if the wind stops where used to illustrate these concepts. The students were asked to talk about other things that the wind moves (e.g., tree branches, ocean waves, sailboats, kites, flags). A pinwheel was used in the conclusion of the small group activity to discuss how wind power can be collected and stored using wind mills.

3. Survey Results

For the last three activities, a multiple-choice survey was handed out to the class to assess if the students enjoyed the activity and what they learned. It was challenging to design a survey that would be understandable and meaningful for the kindergarten level. In some cases, the multiple choice answer options consisted of pictures or sketches. For example, the “did you have fun today” question had choices of a happy, indifferent or sad face. In other questions, the choice of answer was a list of words that would already be familiar to kindergarteners plus the new engineering words they learned during the activity. The teacher asked students with advanced reading skills to read the question out loud to the class. The teacher then read through all the answer choices and helped the students point to each word as she read it. They were told to circle the one word that they thought was the correct answer. The process of going through the survey gave the students an opportunity to apply what they were learning in reading on sounding out words along with allowing us to assess if they could remember the new engineering words they learned in the activity. In several questions, they were asked to write down a one-word answer to a question rather than circling a multiple-choice answer. This gave them practice in matching letters with the sounds in a word and working on their writing of those letters.

Table 1. Survey Results

<table>
<thead>
<tr>
<th>Activity</th>
<th>Format of Choices</th>
<th>Correct Happy Face</th>
<th>Partially Correct Indifferent Face</th>
<th>Incorrect Sad Face</th>
<th>No Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand Castle Activity</td>
<td>pictures</td>
<td>14</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1. Did you have fun today building sand castles?</td>
<td>pictures</td>
<td>10</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. What happens if you mix too much water into the sand?</td>
<td>pictures</td>
<td>10</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. What happens if you use dry sand?</td>
<td>pictures</td>
<td>10</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Which sand castle has the best foundation?</td>
<td>pictures</td>
<td>13</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Which mold should you use when building the bottom of your sand castle?</td>
<td>pictures</td>
<td>12</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Which mold should you use when building the top of your sand castle?</td>
<td>pictures</td>
<td>12</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tower of Coins Activity</td>
<td>pictures</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Did you have fun today playing with the tower of coins?</td>
<td>pictures</td>
<td>12</td>
<td>5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2. Circle the two new words you learned about today in our engineering activity.</td>
<td>words</td>
<td>14</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. What stops a ball from rolling forever?</td>
<td>words</td>
<td>14</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. How can you make an object that is at rest start to move?</td>
<td>short answer</td>
<td>11</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind Power Car Activity</td>
<td>pictures</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Did you have fun making a car today?</td>
<td>pictures</td>
<td>12</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. What force was used to make the car move?</td>
<td>words</td>
<td>17</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. What force between the wheels and the table resisted the car moving?</td>
<td>words</td>
<td>12</td>
<td>7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The multiple choice answer options for question 1 were a happy face, indifferent face and sad face.*
The results of the surveys confirmed what we saw in the faces of the students during the activities. They were enthusiastic, interested and eager to be involved. In almost all cases, they circled the happy face as the answer for having fun in the activity. The percentage of correct answers on the questions to assess what they learned was encouraging. For the most part, the students picked up the basic engineering concepts being taught. They were learning new words such as inertia and fulcrum and retaining this knowledge. In subsequent sessions, the teacher would start by asking the class if they remembered what they learned during the last engineering activity. Not only did they remember the activity, but were also able to recall the basic concepts and new engineering words they had learned 2 – 3 weeks earlier. The retention of this knowledge was encouraging for both the teacher and the engineering professor.

4. Integration into Kindergarten Curriculum and Implementation Strategy

Kindergarten teachers are responsible for meeting the school district’s educational requirements for the kindergarten level. The curriculum emphasizes the importance of academics such as reading, math, science and problem solving and also focuses on the students’ social and emotional development. They are given some flexibility in trying new methods and ideas along with using the established best practices in kindergarten education. Thus, the teachers have to make conscious decisions regarding what curriculum choices and activities work well for their students while meeting the school district’s educational requirements.

Hoover Elementary School is part of Independent School District (ISD) 77. The district uses Everyday Mathematics for its math curriculum and 2005 Macmillan-McGraw Hill Science for science. Both of these focus on real-life problem solving and everyday experiences in their curriculum. The reading curriculum, 2006 Macmillan-McGraw Hill Treasures, is also based on themes that are relevant to their everyday lives. The topics for the engineering activities were selected to integrate with the unit themes currently being covered in the mathematics, science and reading curriculums.

The partnership between an engineering professor and kindergarten teacher made it feasible to integrate the engineering activities into the curriculum with only a minimal interruption of the normal routine. The Everyday Mathematics curriculum was typically covered during the afternoon through whole-group instruction followed by small group, partner or individual activities. Stations were regularly used to give each student the opportunity to work in a variety of different groups settings while learning, applying and completing new skills. These station activities balanced teacher-directed instruction with opportunities for open-ended, hands-on explorations, long-term projects and on-going practice of skills. The students rotated through approximately four stations in small groups of 4 – 5 students with each station lasting approximately 10 minutes. The stations were based on the Everyday Mathematics curriculum along with integration of science, reading and problem solving.

On five occasions this past spring, an engineering activity related to the lessons or units they were focusing on was used as one of the stations. The large-group instruction time for that day was used to read a book or perform a demonstration related to the engineering concept the students would be learning about. This strategy of implementation fit the engineering activity into the normal classroom routine. Since the afternoon stations were followed by free time, it
worked well to pull any extra time required for the engineering station out of the free time allotment. The students were so eager to have extra time to play with the engineering activity, that the station was also kept set-up and supervised during the remaining free time.

With each session, we learned more about how to effectively implement the activities through large group story time or demonstration followed by small group, hands-on activities. Throughout the process, we also gained experience on the logistics of implementing each activity at a kindergarten level. Field notes were kept regarding these logistics and will be used to improve future implementations. For example, the most effective group size was determined to be 3 – 4 students. When the small groups consisted of 5 students, it was significantly more challenging to keep everyone in the group paying attention to the discussion of the engineering concepts and calming taking turns with the hands-on component. We also experience some challenges in groups focusing on their current station. They were so eager to participate in the engineering activity that is was distracting them from the learning taking place at their current station. Thus, the students had the opportunity to work on their skills in patience and focusing on the task at hand while they waited their group’s turn to rotate into the engineering station.

This initial experience of bringing engineering concepts into a kindergarten classroom was based on implementation in one classroom through the partnership of an engineering professor and kindergarten teacher. A broader group of students could be reached by expanding future implementations to include all kindergarten classrooms in a school or even across the district. Suggestions for this type of larger scale implementation would be to draw on the resources of college student organizations at the university such as the America Society of Mechanical Engineering (ASME), American Society of Civil Engineer (ASCE) or Society of Women Engineers (SWE). An engineering faculty member could organize and coordinate the engineering activities and draw upon these student organizations for volunteers to effectively bring the activities into multiple classrooms and multiple schools in the district. This would have the added benefit of providing an opportunity for these college students to volunteer and serve the community using their chosen major. It would give them the opportunity to share their passion for engineering and instill those concepts into future engineers.

5. Benefits for Kindergarten Teacher and Engineering Professor

Benefits for the engineering professor included both professional development and involvement in community service. The professional development plan for tenure and promotion at Minnesota State University, Mankato outlines five key areas in which faculty members are expected to grow and contribute. Community service falls within one of these areas and is recognized by the university as a valuable contribution. The engineering professor enjoyed having this opportunity to use her knowledge and training to motivate young students to consider engineering. The excitement of the kindergarten students as they worked on the various activities was rewarding and encouraging. The professor also used this experience to sharpen her skills in adapting engineering concepts to be understandable by people with various levels of background knowledge. In this case, the kindergarten students provided an extreme case in adapting concepts to basic explanations that are fun, easy to understand and connected to everyday life. Engineering concepts seen at this basic level is a valuable viewpoint to have even when developing lectures for engineering courses at the university. Furthermore, developing
professional connections with elementary education is beneficial for engineering departments and universities as they focus on the K-12 pipeline for future engineering students.

Benefits for the kindergarten teacher included learning about engineering applications and how to integrate them into various areas of the kindergarten curriculum, developing collaboration with engineering faculty, and experiencing the excitement of the students as they participated in the hands-on activities. Opportunities to bring parent and professional volunteers from the community into the classroom are beneficial for both the teacher and the students. The power of collaboration through a program like this allows that partnership to extend from professor to teacher, teacher to student, student to professors alike. It creates a new community of explorers that take what they are learning in the classroom and applying it in new and challenging ways. It was exciting for the teacher to see the students work, explore, and investigate together to learn new concepts. It creates an inviting atmosphere where students, teachers, and professors are excited about what they are learning and how they are learning it.

References


Biographical Information

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Assessing the Written Communication Skills of Graduating Mechanical Engineering Students

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Abstract
The Accreditation Board for Engineering and Technology (ABET) Criterion 3(g) requires engineering programs to demonstrate that their graduates have attained the ability to communicate effectively. To develop students’ communication skills, the mechanical engineering program at Minnesota State University, Mankato (MSU) requires all students to take the English Composition class and one additional course in either Public Speaking, Public Speaking for Technical Professionals, or Technical Communication. In addition to standard lab and project reports, during the senior year, students are required to take the mechanical engineering seminar class and write a half-page summary discussing what they gained from listening to presenters from industry. Each week a presenter shares his or her professional experience with the seminar class and talks about career paths, ethics, continuing education, and the “dos” and “don’ts” of a professional. The summaries are read for both content and proper use of grammar and sentence structure, and points are deducted for improper use of grammar and misspelled words. The seminar class is the last opportunity to assess our students’ written communication skills. In this paper we will discuss the collaboration between an English graduate student (first author) and a mechanical engineering professor (second author) to assess and improve the written communication skills of mechanical engineering students at MSU. We will present the common mistakes that are made by graduating seniors and an intervention method to correct them, as well as discuss the need for and success of the intervention.

Introduction
Over 300 colleges and universities in the United States offer bachelor’s-degree programs in engineering that are accredited by the Accreditation Board for Engineering and Technology (ABET). ABET examines the credentials of the engineering program’s faculty, curricular content, facilities, and admissions standards before granting accreditation [1]. In this paper, we focus on ABET Criterion 3(g), which requires engineering programs to demonstrate that their graduates have attained the ability to communicate effectively. At Minnesota State University (MSU), to develop our mechanical engineering students’ communication skills, we require all students to take the following courses. The values in parentheses indicate the number of semester credits associated with each course. The course descriptions are taken from the MSU website [2].

ENG 101 (4): English Composition: Students will practice strategies for generating and developing ideas, locating and analyzing information, analyzing audience, drafting, writing sentences and paragraphs, evaluating drafts, revising, and editing in essays of varying lengths. Students will also become experience in computer-assisted writing and research.

and

Proceedings of the 2010 ASEE North Midwest Sectional Conference
**ENG 271 (4) Technical Communication:** Introduction to learning the written and oral communication of technical information. Assignments include writing and presenting proposals, reports, and documentation. Emphasis on use of rhetorical analysis, computer applications, collaborative writing, and usability testing to complete technical communication tasks in the workplace.

or

**CMST 102 (3) Public Speaking:** A course in communication principles to develop skills in the analysis and presentation of speeches.

or

**CMST 233 (3) Public Speaking for Technical Professionals:** This course is designed to introduce and develop the skills and knowledge necessary to create and present effective public communication of technical content for a technical or general audience.

In addition to these courses, students are required to write laboratory and design project reports in many of their mechanical engineering courses such as Introduction to Problem Solving and Design (ME 201), Engineering Analysis (ME 291), Mechanical Engineering Experimentation I (ME 336), Mechanical Engineering Experimentation II (ME 436), Mechanical Engineering Experimentation III (ME 446), Mechanical Engineering Design Project I (ME 428), and Mechanical Engineering Design Project II (438). During the senior year, students also are required to take the mechanical engineering seminar class and write a half-page summary discussing what they gained from listening to presenters from industry. Each week a presenter shares his or her professional experience with the seminar class and talks about career paths, ethics, continuing education, and the “dos” and “don’ts” of a professional. The summaries are read for both content and proper use of grammar and sentence structure, and points are deducted for improper use of grammar and misspelled words. The seminar class is the last opportunity to assess our students’ written communication skills. In the past, the mechanical engineering professor in charge of the seminar class read the summaries. However, last year, in order to have a direct assessment of students’ written communication skills, a professor of mechanical engineering collaborated with an English graduate student to study the common mistakes made by students and find ways to intervene and reduce mistakes before they graduate. In the following sections, we will discuss the class profile, typical written mistakes, the intervention method, and the results of our findings.

**The Class Profile**
The seminar class consisted of 31 students with the following composition: three international and 28 domestic. Eighteen of these students received A (17 domestic, 1 international), ten received B (8 domestic, 2 international), and three students received C (all domestic) grades for their efforts in the English Composition class. Moreover, eight students took the Technical Writing course, while seventeen students took the Public Speaking class, and the remaining six students took Public Speaking for Professionals. The distribution of grades for each of the mentioned classes is shown in Figure 1.
Our data shows minimal correlation between grades received in required English and communication courses (see Figure 1) and grades received for grammar and communication in the mechanical engineering seminar prior to the intervention (see Figure 3). The fact that students typically scored much higher in ENG 101, ENG 271, CMST 102, and CMST 233 than they scored on their senior seminar writings indicates a problem. Either students lost or did not use the skills they displayed in their earlier English and communication coursework, or student grades fail to reflect students’ lack of grammatical correctness and clarity in these courses. We believe that an increased focus on correctness and clarity in ENG 101, ENG 271, CMST 102, and CMST 233 combined with regular interventions and reinforcement in other coursework would ensure that students continually improve their communication skills between freshman and senior year. The details of our intervention as well as a suggested system of intervention and reinforcement are discussed below.

**Figure 1** The grade distribution in ENG 101, ENG 271, CMST 102, and CMST 223.
Typical Written Mistakes
During the first half of the spring semester, we did not inform the students that their summaries were being examined in detail for typical mistakes. After the spring break, we intervened and informed the students about the mistakes that they commonly made.

Although students exhibited a variety of grammatical errors, as well as occasional errors of spelling or word choice, the few errors that occurred most often included improper use of or omission of commas, improper use of semicolons, improper use of you in the memo format, inconsistent use of person, and unnecessarily lengthy or fragmented sentences. Students often referred to you in the weekly memos when the advice or information was directed at fellow classmates rather than at the reader of the memo. In addition, many students switched between using first, second, and third person pronouns to describe the same subject or object within the same paragraph or even within sentences.

Intervention
The English graduate student began reading and copyediting student papers and determined a weekly grade for each student based on the number and level of errors within the given paper. This grade was given on a ten-point scale. These marked-up papers were returned weekly to the mechanical engineering professor, who returned the papers to his students. An in-class presentation by the English graduate student was scheduled for the week following spring break. By this time, students would have received written feedback on seven individual papers. Using an experienced outside source to edit and grade student papers allowed for an unbiased assessment of student skills and a more authoritative presentation on correcting errors than if the mechanical engineering professor had undertaken this assessment and intervention on his own.

We decided that it would be most productive to focus on a few common errors that appeared in many students’ papers. We chose to focus on the five mistakes listed above and created a handout that explained each error and gave an example of correct usage or tips for correcting the error. In addition, the first author used sentences taken from the last edited papers to compose a handout exhibiting these errors. The handout consisted of 11 sentences, each taken from a different student’s paper. These are shown in Tables 1 and 2. During the class period, students received both the informational handout and the worksheet. Following a brief introduction and explanation of common errors and how and why to avoid them, presented by the English graduate student, students had the opportunity to ask questions about technical writing or the correct use of the English language. Finally, students were given approximately 20 minutes to correct or improve the sentences in the handout. Students were asked to volunteer their improvements. Additionally, the presenter displayed her own improvements to demonstrate the many options available for increasing sentence correctness, clarity, and conciseness.

After the presentation, student papers continued to be edited and graded as usual. We coded the above-mentioned errors for each student each week in order to track the occurrence of each error and any improvement.
Table 1 The intervention handout

<table>
<thead>
<tr>
<th>Polishing Professional Writing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Second person (you):</strong></td>
</tr>
<tr>
<td>Use “you” when directly addressing the reader. In a memo, the reader is listed in the “To:” line.</td>
</tr>
<tr>
<td><em>Example:</em> You will find the necessary data attached.</td>
</tr>
<tr>
<td><strong>Consistency with person (e.g. his, him):</strong></td>
</tr>
<tr>
<td>Use the same subject throughout the sentence.</td>
</tr>
<tr>
<td><em>Example:</em> I find this information valuable because my coworkers always ask me about grammar.</td>
</tr>
<tr>
<td><strong>Commas:</strong></td>
</tr>
<tr>
<td>Use commas after an introductory clause (if it’s still a complete sentence without the portion before the comma).</td>
</tr>
<tr>
<td><em>Example:</em> If there is ever a conflict, the documented work will be available.</td>
</tr>
<tr>
<td>Use “because” or “and” to separate complete sentences, or begin a new sentence.</td>
</tr>
<tr>
<td><em>Example:</em> Apply for as many jobs as possible, and follow up with workplace contacts.</td>
</tr>
<tr>
<td><strong>Semicolons:</strong> Use semicolons rarely.</td>
</tr>
<tr>
<td>Use to separate complete sentences that are closely related.</td>
</tr>
<tr>
<td><em>Example:</em> Engineering is not about coming up with the best design possible; it is about doing the best you can with what is available.</td>
</tr>
<tr>
<td><strong>Concise sentences:</strong> Clear, active sentence usually aid understanding.</td>
</tr>
<tr>
<td>Be sure that each sentence contains a complete idea—at least a subject and verb.</td>
</tr>
<tr>
<td>Be sure to complete the idea when using dependent clauses.</td>
</tr>
<tr>
<td>Tell the reader what the subject did, rather than what was done to the subject.</td>
</tr>
<tr>
<td>Remove unnecessary or repetitious words or phrases.</td>
</tr>
<tr>
<td><em>(See examples of concise sentences in the second column of Table 2 below.)</em></td>
</tr>
</tbody>
</table>

Table 2 Examples of student mistakes and suggested corrections
<table>
<thead>
<tr>
<th>Students’ Examples</th>
<th>Suggested Corrections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tips such as working harder than anyone else, being able to build what is designed on the computer, taking advantage of every opportunity, and finding a way to work on something you enjoy are all of what Brian recommended to us.</td>
<td>Brian recommended that we work harder than anyone else, be able to build what is designed on the computer, take advantage of every opportunity, and find a way to work on something we enjoy.</td>
</tr>
<tr>
<td>As Brian has also found out by his recent promotion is that it does indeed pay off to work harder than everyone else around you because when opportunities arise you will the companies first pick to fill that position.</td>
<td>Brian found out by his recent promotion that it pays off to work harder than everyone else around him because, when opportunities arose, he was the company’s first pick to fill that position.</td>
</tr>
<tr>
<td>Allen said that, anything can be designed in Pro-E, but can it be built?</td>
<td>Allen said that anything can be designed in Pro-E. The question is, Can it be built?</td>
</tr>
<tr>
<td>That if you want to be successful you need to work harder than everyone else because you will learn from it and it will definitely be noticed, both internally, and externally, if you put in the time.</td>
<td>If we want to be successful, we need to work harder than everyone else because we will learn from it, and it will definitely be noticed, both internally and externally, if we put in the time.</td>
</tr>
<tr>
<td>Some other things that I learned were; it’s important to document our work, communication is critical, and to find a job you enjoy.</td>
<td>I also learned that it’s important to document our work, communicate effectively, and find jobs that we enjoy.</td>
</tr>
<tr>
<td>Another statement said by Mr. Allen, is that, “Engineering is not necessarily coming up with the best design possible for a given application.”</td>
<td>Mr. Allen also said, “Engineering is not necessarily coming up with the best design possible for a given application.”</td>
</tr>
<tr>
<td>What he means with this, is that we should surround with people that are well knowledgeable about a topic that you are working on, surround yourself with online databases that will help you find information that it is related to your project, and surround yourself with software tools that will help you with very complicated projects.</td>
<td>He means that we should surround ourselves with people who are knowledgeable about a topic that we are working on, online databases that will help us find information that it is related to our project, and software tools that will help us with complicated projects.</td>
</tr>
<tr>
<td>For engineers who are fresh out of college, they should work harder than anyone else, and the effort one puts in will definitely be recognized.</td>
<td>Engineers who are fresh out of college should work harder than anyone else, and the effort they put in will definitely be recognized.</td>
</tr>
<tr>
<td>This helps so that one can move up to management due to the fact that the understanding of the company is very important when dealing with co-workers and other company contacts.</td>
<td>An understanding of the company helps one move up to management and is important when dealing with co-workers and other company contacts.</td>
</tr>
<tr>
<td>Brian Allen presented to the Mechanical Engineering Seminar class on some tips that he learned in his experiences at Kato Engineering, and what Kato Engineering is.</td>
<td>Brian Allen presented to the Mechanical Engineering Seminar class about Kato Engineering and tips that he learned in his experiences there.</td>
</tr>
<tr>
<td>Another suggestion he gave us was to always document our work, it helps when you need to go back through and explain what you were thinking if a customer calls.</td>
<td>He suggested that we always document our work because it helps when a customer calls and we need to go back through and explain what we were thinking.</td>
</tr>
</tbody>
</table>

Results
Our coding on the weekly write-up following the presentation on writing and grammar indicates that the students understood the grammatical mistakes addressed and were able to either locate and fix the mistakes or avoid sentence structures where mistakes might occur. The distribution of common mistakes for “before” and “after” the intervention is shown in Figure 2. The average class score for each week is shown in Figure 3. As shown in Figures 2 and 3, as a class, improvements were made. However, toward the end of the semester, many students appeared to backslide and returned to making the same mistakes that their pre-presentation papers exhibited. This may be attributed to lack of time, since they were focused on finishing their capstone and elective senior design projects. Rachel Yarrow’s research suggests that secondary students believe grammar “gets in the way of writing” and is only important for the final draft [3]. This belief may hold true for postsecondary students as well.

Students made the greatest improvements regarding correct use of person. All students eliminated inappropriate references to you, and most students consistently used first or third person following the intervention. The lack of improvement regarding the use of commas following introductory clauses may be due to the complexity of proper comma usage or confusion about the definition of introductory clause. Comma usage in general was a common problem for the students. During the in-class presentation, no student specifically asked any questions about the proper use of commas following introductory clauses; however, some students asked about comma usage in different situations. They may also have felt encouraged to omit a comma erroneously if they were unsure of its correctness because the first author encouraged them to omit semicolons in the same instance.

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**Figure 2** The distribution of common mistakes before and after Intervention
Figure 3 The average class write-up scores for each week. Week 8: Spring Break, Week 9: Intervention

Concluding remarks
ABET Criterion 3(g) would be met more fully through increased classroom support. Although mechanical engineering students quickly discover that sloppy memos and reports are not tolerated in the workplace, the ABET standards indicate that students should understand this before graduating from college. We recommend that interventions be introduced earlier and more often in order to produce more lasting results.

Students appear able to understand and employ grammatical rules; however, they appear to find them less important than other elements of the writing process, especially when influenced by time constraints [3]. This also indicates that grammatical rules require thought and do not come naturally to many students. Communication courses, especially English 101, may improve student performance by focusing more on grammatical correctness. Additionally, instructors in all disciplines should encourage grammatical correctness and clarity when evaluating student writing. In order to serve our students more effectively, we must ensure that students understand the importance of clear and correct communication and that we address common errors when and where they occur, even outside of the English classroom.

Despite the existence of common grammatical errors in the students’ papers, the students demonstrated improvement from the beginning to the end of the seminar course. We recommend that this type of intervention be introduced and regularly reinforced earlier in the students’
academic careers in order to achieve more positive and permanent results. For example, in our mechanical engineering program, professors should consider teaming with English graduate students or faculty to provide a direct assessment of students’ communication skills. This idea could be expanded to invite experts from the Communication Studies department to provide a similar type of assessment. Ideally these assessments would begin in courses such as Introduction to Problem Solving and Design (ME 201), Engineering Analysis (ME 291), and Mechanical Engineering Experimentation I (ME 336), culminating in Mechanical Engineering Experimentation II (ME 436), Mechanical Engineering Experimentation III (ME 446), Mechanical Engineering Design Project I (ME 428), and Mechanical Engineering Design Project II (ME 438).

These assessments and interventions should be based on actual student writing and should address errors and problems as they appear. Additionally, students should be encouraged to identify and correct their own errors, possibly by receiving a secondary grade for clarity and correctness. If partnerships between departments prove difficult to implement or sustain, individual instructors can still improve their students’ skills by addressing grammatical correctness and clear communication in relevant coursework. By devoting a small amount of class time to identifying and correcting common errors in student writing, instructors across the disciplines will better prepare their students to satisfy ABET Criterion 3(g) as well as to succeed in the workplace.

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1. http://www.abet.org
2. http://www.mnsu.edu
Letting the Course Follow the Topic

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Minnesota State University, Mankato

Abstract

This paper builds on an earlier paper which chronicles an experiment in teaching a graduate level seminar in engineering management. In the original experiment the students developed the syllabus details to include which subjects to address and the grading scheme. Thus the course addressed topics of interest to the students and for which they were in turn required to find appropriate reading and research material. A different but similar course using this technique is reported as well as the use of the techniques in non-similar courses.

Background – The First Experiment

As previously reported (Peterson, 2001) in the winter semester of 2000 I was assigned to teach a graduate seminar in engineering management for the first time. The course was an elective in two overlapping master’s programs – one in industrial engineering and one in engineering management. The course was offered off-campus over a 12-week period. Each class was a three hour and twenty minute block that was to start at 6:00 PM. The catalog’s course description (Western Michigan University, 2000) of the course was as follows:

“ISE 622 Industrial Supervision Seminar (3-0) 3 hrs
An analysis of the writings, literature, and philosophy concerning line supervision and employee direction in manufacturing industries. Prerequisite: IME 600 or permission of the instructor”

The course’s title had been changed to Engineering Management Seminar since the catalog was published and its description had been expanded to include advanced engineering management topics such as change management. The course’s coordinator normally taught both the course and its prerequisite. Typically there was a reading packet for this course but as no specific topics needed to be covered during the course each instructor was free to take a different approach.

With the ground rules for the course established, the standard next step was to develop a course plan - course objectives, a syllabus, a grading scheme, and a reading plan for the course based on what should be taught. But by stepping back and applying engineering management and adaption of new technology principles, the first step became to rethink the course’s presentation. What is a seminar? Webster’s (Neufeldt, 1988) defines it as:

“seminar…1 a group of supervised students doing research or advanced study, as at a university, 2 a) a course for such a group, or any of its sessions b) a room where the group meets 3 any similar group discussion”
Discussion, research, and advanced study seemed to be the key concepts in both the course and in a seminar style of presentation.

The next step was to consider the students in the class. The typical students in these programs were working professionals with several years experience as individual contributors. Some had started supervising professional employees but many had not. The students seemed most interested in concepts that they could immediately apply on their current assignment.

The next step was to review those graduate courses that had appealed to me as a practicing engineering manager. An upper level course Dr. Al Miller presented at The Ohio State University started with a question about what the students wanted to cover or get out of the course which he worked into his lecture and assignments for the course. This approach made a lasting impression on me.

The final step was to review making assignments in an industrial setting to engineers and engineering managers - state my perception of the task and ask for input on solutions to address the task (or to redefine the problem and thus the task). The team who would be assigned the task would then develop a plan (who, what, when) with which both the team and I could all agree. “Could this be done effectively in an academic setting?” became the experiment’s question. I thought it could be done. I saw several potential benefits and several potential pitfalls. The benefits included student buy-in to the course, higher student satisfaction, practitioner-relevant topic selection, reduced instructor workload in reading-material preparation, and increased student involvement in classroom discussions. The potential pitfalls included inappropriate topic selection, increased preparation to cover student-selected topics outside my expertise, an unreasonable evaluation plan, and a student resistance to the concept of setting their own plan of study. The potential benefits were seen to outweigh the potential pitfalls. The resulting experiment was to manage the course as an engineering manager should manage an engineering department with the team setting the goals and project plan subject to managerial approval.

The first night of class I arrived with a syllabus which contained the basics – course description, details of when the course met, my grading philosophy, my contact, and my office hours. The only class topic on the syllabus was that night’s – “Introduction and Course Development”. After introducing myself to the class, I offered them the opportunity to develop the remainder of the syllabus for the course based on the class’s needs and desires, subject to the provisions that the class meet, accomplish the course description, and that a grade be assigned by the instructor. The option being that I could publish a traditional instructor-driven for the course. To get started in setting up the course plan I asked the students what they wanted to get out of the class besides a grade and meeting a degree requirement. This lead to a subdued discussion with the consensus that they wanted to get something they could use out of the course. From here we started listing the board topics and concepts they were interested in studying. A fairly large list was developed which was then grouped into general headings using typical brainstorming techniques.

Next we discussed how we were going to cover these topics. I offered the idea that the students pick the materials to read on the course topics. After discussion it was agreed that each student would find three articles on each night’s topic and at the least one of the articles would be from a refereed journal. This required each student to do his or her own research on the topic and to find
articles they found interesting. In turn at each class there would both small group and class
discussion of the topics, the articles, differing opinions, and how to apply the material at work. I
agreed to supplement their research with brief presentations of material that I believed were
important, such as change management. I agreed to lecture in week two and they would bring in
one article on the topic. This allowed the class some time to get their articles and to try out the
class format and my expectations.

I then asked for grading suggestions. After we went through the inevitable suggestion of all
getting an “A”, we discussed the merits of purely subjective – the instructor would somehow
pick one – and a mix of objective and subjective – you do something, I’ll publish expectations
prior to the assignment, and I’ll judge how you did. The mix was the unanimous choice. The
final class decision was 30% for participation (getting the three articles, being in class, being
ready to discuss the topic, and actively being in the discussions), 20% for a short report and its
subsequent presentation (to allow the students to calibrate the grader), and 50% for a long report
and its subsequent presentation (to allow the students to demonstrate their ability to apply what
they learned in the class).

The resulting class meetings were lively with small group discussions of their articles (and very
seldom did two people have the same article) and opinions in those articles, class discussions of
the group sense of their articles, instructor lead discussions of the topic’s implications for
engineering managers, and question and answer periods to the instructor on topics that grew
from the earlier segments of the class. The short paper and presentation were on a “new” or
“current” concept in management that the student would like to introduce into their specific
company. The long paper and presentation were on how they would/will go about introducing
their concept into their specific company with particular emphasis on obstacles and how they
would be addressed and conditions which support implementation and how they will be taken
advantage of. With one exception the papers were very good to excellent as were the
presentations. Both the students and the instructor critiqued the presentations. One question
asked of the students was their willingness to be involved in the presentation. This question
drove home the requirement to sell a program to the audience in its presentation.

This driving home a point was discussed the last night of class. After the grades were handed out
and the student course evaluations were completed, I made a brief presentation of why I did what
I did during the course and what I wanted them to take away from the course. The students were
then free to leave, but I offered to stay and open the floor to questions – no one left. We
continued the discussion for over an hour before losing any of the students. Two students talked
for about two hours.

The Second Experiment

In the 2007-2008 academic year at Arizona State University while teaching in a MS program in
Technology (Management of Technology) there was again the opportunity to teach a course
similar to the one in the first experiment. In this experiment the course was OMT 598, Special
Topic: Seminar in Technology Management. OMT 598, Special Topics, was a placeholder
course which could be just about anything but which when taught had the specific topic listed so
it showed as such on the student’s transcript.
The basics were a 15 week course, taught one night a week for 3 hours per night. The students were a mix of full time graduate students and working professionals. The full time graduate students were mainly international students with some practical experience in their undergraduate discipline.

Enrollments in the program were low but being rebuilt – this course was being offered as part of the rebuilding process in which the structure of the program was being repositioned and an emphasis on attracting working professionals was being implemented.

As with Western Michigan Michigan’s students there was a desire for “stuff” the students could use immediately and in the case of the full time students for “stuff” that they saw a benefit from learning.

In this experiment the same approach was followed: pretty blank syllabus the first night which the students had to populate with items of interest. Unfortunately in this version of the original experiment the number of students was small (5). This small number had a negative impact on topic generation and required a significant contribution from the professor. The small size made the group breakout sessions during class less natural and somewhat impractical. The resulting class discussion was meaningful but had a larger instructor presence than in the original experiment which was less desirable than more peer to peer discussions/arguments.

Again the students were involved, rated the course high, and seemed to learn from the experience. From an instructor standpoint, a better understanding of this student group was possible and it did contribute to program redefinition and content.

**Applying the Approach to Non-Seminar Courses**

For the last three semesters, MET 600 at Minnesota State University, Mankato has had elements of this approach incorporated. From the graduate bulletin (Minnesota State University Mankato, 2009):

“MET 600 (2) Manufacturing Research Methods
Research topics and methods related to manufacturing. The course will look at the current state of manufacturing and explore the research methods and experimental design procedures that are used in the area of manufacturing. Student will evaluate past research and will design a research project in manufacturing.”

The first of the three offerings of this course was a last minute assignment to cover a need – to graduate several students needed the course then. Thus the assignment went to the new faculty member since the teaching of the course was not popular. This assignment was also added within a week of the class meeting.

An analysis of the course description and the curriculum seemed to indicate that as in the two earlier mentioned courses this course has an element of flexibility as to coverage and how to get that coverage. The syllabus for this course is minimal. The details are partially provided from student expectations and the remainder is driven by issues raised in completing the unifying task.
for the course. The text book is a research book appropriate to their field. The writing style manual is the one they will be using to document their capstone paper

The approach taken incorporated several elements and philosophies from the earlier experiment: immediacy of application, student need driven, learn-by-doing/applying (finding how to find and then use their own resources). Since the written goal of this course is to prepare the student to do the research necessary to successfully complete their thesis or alternate plan paper (applied project) this requirement became the basis for the course.

The students in the class have typically include a mix of majors – manufacturing engineering technology and mechanical engineering – and mix of thesis (all mechanical engineers plus a few manufacturing engineering technology student) and applied project papers. The class size has ranged from 12 to 15.

The basis for the course has become the proposal the student will need to make prior to starting their capstone research project. By using the student’s own research topic we provide relevance to the research and since they need to submit a proposal soon after the course if they want to graduate in a reasonable time period (2 years or less). Since we use their topic, the research they read and report on is relevant to their study.

The use of breakout session to discuss problem statements, deliverables, and methodology give the students opportunities for peer to peer review and critiques. Since the class has some working professionals and a mix of majors, the peer to peer feedback is diverse and seems to positively impact quality.

**Recommendations**

This approach can work well with mature, motivated graduate students. Use this approach with undergraduates is questionable. The approach only works for those well grounded in both the theory and practice of the course topic and try to stay current via readings and conference attendance.

The class needs to be looked at carefully because as the size increases the effectiveness may suffer. On the other hand too small a size causes other problems. Groups of three to five students for breakout sessions seem best. The instructor can listen in if there are multiple groups during the breakout sessions but the peer to peer interaction is key.

Teaching a graduate level course in this manner can be challenging - the instructor has to be willing to risk getting topics, which will require research on his/her part if the students want to go outside your comfort zone. This is an inherent risk in letting the students set the agenda within a wide set of boundaries.

In the class format discussed in this paper the instructor must explain why the assignments are given, what the students should expect to get out of them, and how what we did in the class applies.
References


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Insights Learned from Conversion of Web-Based On-Line Courses Back to Traditional Classroom Presentations

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ABSTRACT
Manufacturing Engineering Technology classes at Minnesota State University in Mankato, Minnesota, including Industrial Safety, and Logistics, had been converted from traditional classroom presentations to web-based on-line classes. We discovered that there were some advantages to on-line courses, such as enhancing presentations, grading homework, and assisting students who missed a class. But, due to time and budget problems and security concerns, these classes were later converted back to classroom presentations again. We found that on-line courses require more time and hardware than traditional classes. There are more costs, some hidden, which also must be considered when developing or converting on-line classes. There are also problems concerning copyright infringement and exam security. This paper provides a case study which discusses reasons for the original conversion, reasons for changing back, and lessons learned concerning presentations, time involved, student progress assessment, scheduling, and results. Information is presented to help departments considering web-based courses with the planning and resource development needs.

Advantages of Web Courses – Why Courses were Converted to On Line Delivery

Two Manufacturing Engineering Technology classes at Minnesota State University in Mankato, Minnesota, Industrial Safety, and Logistics, were converted from traditional classroom presentations to web-based on-line classes. Like many engineering technology departments which are considering development and implementation of new web-based college courses, or converting traditional face-to-face college classes into on-line courses, our primary goal was to reach more students by offering flexibility and reducing travel. There were other advantages we hoped to obtain, as well.1

The internet and modern computers and programs offer the opportunity for universities to offer some classes partly or completely over the internet. Mail-order correspondence courses have offered remote learning opportunities for many years, but results and quality of education have been mixed, at best. On the other hand, the internet can provide real-time chat-room discussions, videos, and feedback not possible by mail. Web-based college classes can provide education opportunities to a much wider group of students.

Because our Manufacturing Engineering Technology program includes a two-semester Senior Design Project, some students must travel between the company and the university classes on a regular basis. Some out of town students take the first two years at their local community college, and then complete their four-year Bachelor’s of Science degree in Manufacturing
Engineering Technology here. Web-based courses would allow these students to spend less time away from their homes, saving them money while attracting more students.

We decided to put our senior classes on the web to allow students to take these classes remotely. Because we did not have the faculty or budget to also offer these classes face-to-face, it was initially planned to make all senior classes web-based over a period of years. In 2003, the Minnesota State Colleges and University System (MNSCU) was instituted to assist state campuses in developing on-line curricula and services\(^2\), and, in 2004, provided grants to the MET program to put classes on-line.\(^1\) We chose to implement an almost-entirely web-based format, with only one on-campus class meeting per semester to provide lab and presentation time, and one classroom exam. Figure 1 shows the initial plan for course conversion.

<table>
<thead>
<tr>
<th>Course Title and Credit</th>
<th>Face-to-Face Component</th>
<th>First Online Ready Term</th>
<th>Enrolled Initial Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing Resource Planning &amp; Control (4 credits) undergraduate</td>
<td>Capstone Project Required</td>
<td>Spring 2006</td>
<td>21</td>
</tr>
<tr>
<td>Manufacturing Resource Planning &amp; Control (4 credits) graduate</td>
<td>Capstone and Industry Applied Project Required</td>
<td>Spring 2006</td>
<td>5</td>
</tr>
<tr>
<td>Ergonomics &amp; Work Measurement (4 credits) undergraduate</td>
<td>Mid term face-to-face Lab</td>
<td>Spring 2007</td>
<td>23</td>
</tr>
<tr>
<td>Project and Value Management (4 credits) undergraduate</td>
<td>Capstone Project Required</td>
<td>Spring 2006</td>
<td>19</td>
</tr>
<tr>
<td>Project and Value Management (4 credits) graduate</td>
<td>Capstone and Industry Applied Project Required</td>
<td>Spring 2006</td>
<td>3</td>
</tr>
<tr>
<td>Quality Management Systems (3 credits) undergraduate</td>
<td>Mid term Lab</td>
<td>Fall 2006</td>
<td>23</td>
</tr>
<tr>
<td>Quality Management Systems (3 credits) graduate</td>
<td>Mid term Lab and Industry Applied Project</td>
<td>Fall 2006</td>
<td>2</td>
</tr>
</tbody>
</table>

Industrial Safety (2 credits) and Graduate Industrial Safety were later added to the schedule.

In the process of converting and evaluating these classes, we learned about both the advantages and the costs of our venture. As we proceeded, we found that the opportunities of offering classes on-line came with problems and costs which must be considered.
**Problems and Costs of Web Based Classes— Many are Hidden**

The two most visible costs of offering courses on-line were instructor time and the equipment and programs which on-line courses required.

Additional instructor time required included filming time, studio scheduling and access time, technical training time, editing time, conversion time, time spent editing and verifying web instruction, copyright and license issues, login and downloading student homework, discussions, drop-box access, and preparing many more slides, scanned materials, etc. In some cases this was more than twice the time that would be required for a face-to-face class\(^5\). Additionally, the Inter Faculty Organization union contract at Minnesota State University does not allow for adequate payment for this extra time, which was often provided by instructors on unpaid weekends.

Another hidden personnel cost was the support staff time required to maintain and correct equipment or program failures and incompatibilities, in addition to the additional instructor time these failures required.

Equipment costs included University studio and audio-visual and editing equipment, servers and storage devices, local computers, computer cameras, green screens, and other materials. Minnesota State University, Mankato, decided to use the D2L on-line delivery system\(^3\), which is an excellent web-based instructional material delivery system, but must be paid for and maintained.

Other issues, costs, and problems of converting classes to on-line delivery included:
1. Copyrights and intellectual property protection laws, which rises to a new level when putting materials on-line\(^4\)
2. License fees, and the problem of live streaming versus Quick Time downloads
3. Exam and homework integrity, as it is difficult to monitor students,
4. Only one (very intense) day of contact for labs, student presentations, and exams
5. Lack of face-to-face interactive contact with and between students
6. Poor student scheduling of study time meant slipped deadlines and student attempts to do multiple weeks’ classes at one time
7. Hardware, equipment, and program compatibility and reliability were continuous problems, especially at start-up
8. Room scheduling was a problem for each single face-to-face meeting, because large blocks of time were required, and the rooms available had already been scheduled for full-semester face-to-face classes.

**Assessments, Time, and Budget Motivated Our Return to Traditional Face-to Face Classes**

Each class included a final student assessment survey to monitor class delivery and effectiveness. A majority of students surveyed indicated a slight preference for on-line courses, but many preferred traditional face-to-face classes; and we found that almost all of these students could meet on campus. The type of class affected on-line student learning and preferences. Classes with little or no laboratory content, such as Industrial Safety (MET 424) and Manufacturing...
Resource Planning and Control (MET 407) gave results similar to or slightly better than face-to-face classes (See Figure 2):

![Graph showing instructional evaluation MET 407 online compared to face-to-face offering]

On the other hand, classes with significant laboratory content, such as Ergonomics and Work Measurement (MET 423) did not do so well. Students received much less laboratory experience, depending on the class. Courses like Automation and Robotics (MET 347) were not ever converted to on-line delivery because of the heavy laboratory content.

Grade distributions of on-line classes were similar to the grade distributions on the former face-to-face classes, but a few students did significantly worse on-line than would have been expected, based on past face-to-face performance. Enthusiasm for the material was harder to generate on-line.

We found that there was less opportunity for student-to-student interaction using chat rooms on on-line discussions than occurs in face-to-face classes. Student teams were not really possible except for the single on-campus meeting. Homework, exam, and quiz security was a significant problem, as well.

But some students reported that the on-line classes made learning easier, homework was easier to do because they could review lectures at will, and a number of students reported that the on-line classes made it possible for them to graduate on schedule. Except for team-intensive and lab-intensive courses, the problems could be mitigated, given enough time and resources, if we had enough time and resources.

However, at this time budgets are tight, and we could not justify added time or dollar costs to continue offering courses on-line. We also found that some on-line college courses were weak
and of poor quality, which led some universities and employers to question the quality of all web-based courses, including ours. Thus the decision was made to return back to offering traditional face-to-face classes, at the present.

**We Converted Back to Face-To-Face Classes, But Retained Many On Line Enhancements**

Although we returned to classroom presentation of courses, in the process we learned that face-to-face traditional courses can benefit from the use of on-line delivery technology. There are some advantages to on-line courses, such as enhancing presentations, grading homework, and assisting students who missed a class, which can be implemented and added to traditional classes with little or no additional time or resource requirements, as long as a good delivery system such as D2L is available. In fact, quizzes administered on-line are much easier to correct, and grades can be posted in a real-time basis using a system such a D2L.

Making Power Point lecture slides which are used in lecture also available to students on-line enables these students to review presentations after class. This also means that they can take fewer notes during lecture, giving them more time to learn and interact. It is quite easy to narrate the Power Point presentations, instead of live filming of lectures, as we found by using narrated Power Points instead of live edited filming when preparing on-line web lectures. In fact, the students preferred narrated Power Point lectures to poorly-filmed lectures with a dim, keystoned, hard to read screen off in the corner. These presentations can be downloaded and reviewed by students multiple times for face-to-face classes, also. This is especially effective when presenting complex calculations.

Handouts can be provided on-line for the students to download, making it unnecessary to duplicate and hand out paper copies during class time. Excel spreadsheets can be used and reviewed by students, and templates provided for complex calculations. Web hyperlinks and videos take students to on-line resources which greatly enhance learning, and take very little preparation time.

By combining the good features of on-line delivery with a single weekly on-campus meeting, the possibility exists to create a new type of hybrid course which combines face-to-face lectures, exams, and labs with on-line delivery of the remainder of the course material. Working students might only need to visit campus once weekly, perhaps on Saturdays.

**Conclusions and Recommendations**

There are a number of advantages to on-line courses, such as reaching more students, helping working students, enhancing presentations, grading homework, and assisting students who missed a class.

But on-line courses require more time, programs, and hardware than traditional classes. There are more costs, some hidden, which also must be considered when developing or converting on-line classes. There are also problems concerning copyright infringement and exam security.
A more detailed breakdown of the positive and negative aspects of web-based engineering and engineering technology courses can be found in the paper, “Online Engineering Technology Courses – the Good, the Bad, and the Ugly”\(^1\). Quality web-based courses require additional commitment of time and resources, but can provide additional benefits to the students. Each course must be carefully evaluated, with as many advantages and disadvantages weighed.

We learned that face-to-face traditional courses can benefit from the use of on-line delivery technology. Putting PowerPoint lecture slides which were used in lecture on-line also enables students to review presentations and take fewer notes during lecture. Homework and handouts can be provided, and Excel spreadsheets can be used and reviewed by students. Web hyperlinks and videos take students to on-line resources which greatly enhance learning, and take very little preparation time. And the possibility exists to create a new type of hybrid course which combines face-to-face lectures and labs with on-line delivery of the remainder of the course material.

The MET program was successful in putting courses on-line; we just did not have the resources to continue. But the experience gave us the ability to provide an enhanced face-to-face classroom presentation of the courses.

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Abstract

This paper discusses the development and continuing refinement of the curriculum for the new Civil Engineering Program at the University of Minnesota Duluth. Included is a discussion of the program objectives, curriculum development, and integration of assessment into the curriculum.

Introduction

The University of Minnesota Duluth (UMD) is a comprehensive regional university located in Duluth, MN. There is an active student population of 11,664 as of fall 2009 enrolment. There are currently 74 different majors available with one of the newest being Civil Engineering. The program started in the fall of 2008 with the first graduating class in 2012. The program was formed because of a need for a civil engineering program in northern Minnesota and was heavily driven by local industry. UMD was well suited to take on this task as they had relatively recently started a new mechanical engineering program and had (and continue to have) a growing number of engineering students. The program had strong support from many local industries including engineering firms located in Duluth, as well as the mining companies that operate within northern Minnesota. This paper discusses the development of the new civil engineering program to date, including the program objectives, curriculum development, and the integration of assessment into the curriculum.

Program Objectives

The program has two main focuses that distinguish it from many of today’s civil engineering curriculums. Both of these focuses are included in the mission statement of the department: “to prepare graduates for professional practice and graduate study through a program firmly based in strong technical skills, fundamentals, hands-on learning, sustainability, and professionalism.”

In recent years, the pressure on engineering programs to reduce the number of credits and to include more liberal education courses at most universities in conjunction with financial pressures had led to the scaling back of laboratory and hands on courses and components [1]. Within the development of the curriculum at UMD it was decided early on that there was a need for a program that emphasized practical, hands on learning while still including the technical
skills and fundamental knowledge that is required to be a successful engineer. In addition to there being a need for this type of program, it was thought that having an intensive hands-on program would result in graduates who are better prepared to enter the workforce. The justification being that even if you are employed as a design engineer, the more practical knowledge you have about what you are designing or where the data you are using comes from, the better the end product will be.

To have a hands-on program it is critical that lab space be readily accessible and equipped for student use. UMD and the Swenson College of Science and Engineering showed considerable foresight when planning the building as they included significant state-of-the-art laboratory space in the new James I. Swenson Civil Engineering Building. The floor plan of the lab level is shown in Figure 1, with a photo of the completed general projects lab shown Figure 2.

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**Figure 1:** 1st Story Floor Plan of Swenson Civil Engineering Building
The second focus area of the curriculum is sustainability. Sustainability has grown in importance over the past decade, and it will only continue to grow as environmental, political, and economical factors increase the need to engineer green structures and systems. Therefore, to ensure that the graduates of UMD are adequately prepared for the workforce it is essential that they have a thorough understanding of what sustainability is, and how to apply it to their profession. As discussed in the next section, this goal is achieved through both classes focused on sustainability and integration of the topic throughout the curriculum. In addition, just as the building provided space for the hands on focus, the building provides examples of sustainable design. The Swenson Civil Engineering Building in which classes are taught is a LEED Gold rated building.

**Curriculum Development**

Once the program objectives were established a curriculum to meet those objectives needed to be developed. When the initial design of the curriculum was established, many outside criteria needed to be met. These included: the liberal education criteria for the university, ABET requirements, requirements from the American Society of Civil Engineers (ASCE), knowledge required for the Fundamentals of Engineering Exam, credit limits established by the university, and the needs of employers. Once these requirements were met, the more difficult part of curriculum development begins: developing the structure of the courses, course subject material and prerequisites, and the availability of technical electives – all with input from faculty and industry. The end result of the curriculum is shown in the program description sheet in Table 1.
<table>
<thead>
<tr>
<th>First Year</th>
<th>Fall Semester</th>
<th>Spring Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intro to Civil Engineering</td>
<td>1 cr</td>
<td>Liberal education course</td>
</tr>
<tr>
<td>General Chemistry I</td>
<td>5 cr</td>
<td>Intro to Programming: Visual Basic</td>
</tr>
<tr>
<td>College Writing</td>
<td>3 cr</td>
<td>Calculus II</td>
</tr>
<tr>
<td>Calculus I</td>
<td>5 cr</td>
<td>General Physics I</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>14 cr</strong></td>
<td><strong>Liberal education course</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Second Year</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering Mechanics</td>
<td>5 cr</td>
<td>Principles of Economics</td>
</tr>
<tr>
<td>Differential Equations w/Linear Algebra</td>
<td>4 cr</td>
<td>General Physics II</td>
</tr>
<tr>
<td>Engineering Statistics</td>
<td>3 cr</td>
<td>Fluid Mechanics</td>
</tr>
<tr>
<td>Global Issues</td>
<td>3 cr</td>
<td>Calculus III</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>15 cr</strong></td>
<td><strong>Engineering Geology</strong></td>
</tr>
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<table>
<thead>
<tr>
<th>Third Year</th>
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<tbody>
<tr>
<td>Soil Mechanics</td>
<td>4 cr</td>
<td>Environmental Eng</td>
</tr>
<tr>
<td>Structural Analysis</td>
<td>3 cr</td>
<td>Public Speaking</td>
</tr>
<tr>
<td>Transportation Engineering</td>
<td>4 cr</td>
<td>Hydrology &amp; Hydraulics</td>
</tr>
<tr>
<td>Infrastructure Materials</td>
<td>4 cr</td>
<td>CAD &amp; Engineering Drawing</td>
</tr>
<tr>
<td>Project Management</td>
<td>3 cr</td>
<td>Liberal education course</td>
</tr>
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<td><strong>Total:</strong></td>
<td><strong>18 cr</strong></td>
<td><strong>Total:</strong></td>
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<tr>
<td>Surveying</td>
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<td></td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>2 cr</strong></td>
<td></td>
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<tr>
<th>Fourth Year</th>
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<th></th>
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<tbody>
<tr>
<td>Senior Design I</td>
<td>3 cr</td>
<td>Senior Design II</td>
</tr>
<tr>
<td>Advanced Writing</td>
<td>3 cr</td>
<td>CE Technical elective</td>
</tr>
<tr>
<td>CE Technical elective</td>
<td>3 cr</td>
<td>CE Technical elective</td>
</tr>
<tr>
<td>CE Technical elective</td>
<td>3 cr</td>
<td>Technical elective</td>
</tr>
<tr>
<td>CE Technical elective</td>
<td>3 cr</td>
<td>Technical elective</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>15 cr</strong></td>
<td><strong>Total:</strong></td>
</tr>
</tbody>
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<tr>
<th>Technical Electives</th>
<th></th>
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</tr>
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<tbody>
<tr>
<td>Structures Focus Group</td>
<td></td>
<td>Transportation Engineering Focus Group</td>
</tr>
<tr>
<td>Advanced Structural Analysis &amp; Design (3.0 cr)</td>
<td></td>
<td>Traffic Systems Operations and Safety (3.0 cr)</td>
</tr>
<tr>
<td>Design of Concrete Structures (3.0 cr)</td>
<td></td>
<td>Highway Planning and Design (3.0 cr)</td>
</tr>
<tr>
<td>Design of Steel Structures (3.0 cr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geotechnical Engineering Focus Group</td>
<td></td>
<td>Water Resources Focus Group</td>
</tr>
<tr>
<td>Geotechnical Design (3.0 cr)</td>
<td></td>
<td>Design of Hydraulic Structures (3.0 cr)</td>
</tr>
<tr>
<td>Rock Mechanics (3.0 cr)</td>
<td></td>
<td>Water Resources (3.0 cr)</td>
</tr>
<tr>
<td>Underground &amp; Surf. Excavations in Rock (3.0 cr)</td>
<td></td>
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Table 1: Typical Program of Study
Within the curriculum it is apparent how the course objectives outlined in the previous section are met; there is a hands-on focused course in each focus area. Courses with a dedicated laboratory component within the civil engineering curriculum include: Soil Mechanics, Transportation Engineering, Infrastructure Materials, Hydrology and Hydraulics, and Surveying. These courses will include laboratories in the field, lab and on computers. In addition to these courses with dedicated lab sections, many upper level courses will include lab based activities, included many of the design classes.

This emphasis on labs does come at a credit cost as each class with a lab has an additional credit. Much of the emphasis of the curriculum development was on determining what knowledge was essential to a civil engineering graduate and determining the best way to package that information into a course. The results are that some of the tradition courses have been removed or altered. One change was to combine what is traditionally 2-3 credit courses (Engineering Statics and Mechanics of Materials) into 1-5 credit course. This served 2 purposes: it eliminated 1 credit of material that was covered in Physics and it allowed students to begin taking many of their Civil Engineering courses 1 semester sooner as these courses are prerequisites for many of the introductory level courses.

Other courses that were removed as requirements include Dynamics and Thermodynamics. The material in these courses was not completely removed as much of it is introduced in Engineering Mechanics, Fluid Mechanics, and Construction Materials. However, it was decided that the material in these courses did not need the extensive treatment that was able to be given in a dedicated course. Care is taken to ensure the basics required for the FE exam are still covered. The result is a curriculum that allows additional credits of lab while still providing sufficient electives.

The objective of sustainability is not as directly apparent within the curriculum though it is just as integral of a component. Sustainability is integrated into all of the courses, most notably Introduction to Civil Engineering, Project Management, and Senior Design. In each of these classes the sustainability (typically related to the LEED rating system) is included as an important aspect of the final project for the class. In addition, there is an upper level elective class dedicated to the topic of sustainability that is available for the students to take.

Assessment

Assessment is an important tool for any curriculum and even more so when that curriculum has not had the opportunity to be evaluated over multiple years [2]. Therefore assessment has been imbedded throughout the development of the curriculum. It has also been emphasized in the recruitment and hiring of faculty members. There are 17 outcomes (a-q) that are assessed to determine the effectiveness of the new curriculum. The first 11 (a-k) are the standard ABET outcomes assessed by most engineering schools. The next 5 (j-p) are based on guidelines provided by the American Society of Civil Engineers. The final outcome was added to further emphasize and provide a means to measure the focus of the curriculum on sustainability. The outcomes are summarized in Table 2.
Table 2: Program Outcomes

<p>| | |</p>
<table>
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<tbody>
<tr>
<td>a)</td>
<td>an ability to apply knowledge of mathematics, science and engineering;</td>
</tr>
<tr>
<td>b)</td>
<td>an ability to design and conduct experiments, as well as to analyze and interpret data;</td>
</tr>
<tr>
<td>c)</td>
<td>an ability to design a system, component, or process to meet desired needs;</td>
</tr>
<tr>
<td>d)</td>
<td>an ability to function in multidisciplinary teams;</td>
</tr>
<tr>
<td>e)</td>
<td>an ability to identify, formulate and solve engineering problems;</td>
</tr>
<tr>
<td>f)</td>
<td>an understanding of professional and ethical responsibility;</td>
</tr>
<tr>
<td>g)</td>
<td>an ability to communicate effectively;</td>
</tr>
<tr>
<td>h)</td>
<td>the broad education necessary to understand the impact of engineering solutions in a global and societal context;</td>
</tr>
<tr>
<td>i)</td>
<td>a recognition of the need for and an ability to engage in life-long learning;</td>
</tr>
<tr>
<td>j)</td>
<td>a knowledge of contemporary issues;</td>
</tr>
<tr>
<td>k)</td>
<td>an ability to use the techniques, skills and modern engineering tools necessary for engineering practice;</td>
</tr>
<tr>
<td>l)</td>
<td>an ability to apply mathematics through differential equations; probability and statistics; calculus-based physics; general chemistry; and geology</td>
</tr>
<tr>
<td>m)</td>
<td>an ability to apply knowledge in the following four recognized major civil engineering areas: structural engineering, geotechnical engineering, transportation engineering, water resources engineering with a depth of focus in one or more of the four areas;</td>
</tr>
<tr>
<td>n)</td>
<td>an ability to conduct laboratory experiments and to critically analyze and interpret data in the following four (4) recognized major civil engineering areas: structural engineering, geotechnical engineering, transportation engineering, water resources engineering</td>
</tr>
<tr>
<td>o)</td>
<td>an ability to perform civil engineering design by means of design experiences integrated throughout the professional component of the curriculum culminating in a senior design experience;</td>
</tr>
<tr>
<td>p)</td>
<td>an ability to explain basic concepts in management, business, public policy, and leadership; and explain the importance of professional licensure;</td>
</tr>
<tr>
<td>q)</td>
<td>an ability to apply knowledge of sustainability to civil engineering practice.</td>
</tr>
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</table>

Included in the development of each course was a discussion of what outcomes would be covered and assessed. In this way all of the faculty members have been involved in the discussion and have a better understanding of the assessment process. By involving assessment at this stage it also allows for the actual assessment itself to become an integral part of the course instead of just an afterthought. When practical for the outcome being assessed the assessment is based on a dedicated in-class assignment that is consistent from instructor to instructor and from year to year. This allows for a more consistent evaluation of the outcome. Another way consistency is ensured is that each assessment is evaluated by two different people, minimizing grading biases.

The results of assessment are stored for each student in each class. This allows the gathering of data that using typical assessment schemes would be difficult to obtain. For example, it is possible to examine how the order in which classes are taken affect the performance of the students, or how the performance in a certain class predicts the latter performance. This allows
for the effect of changes in the curriculum to be evaluated more quickly and more accurately, increasing the benefits of assessment.

Having consistent, integrated assessment can also benefit the instructor. It allows for an unbiased, quantitative evaluation that is very useful for evaluating different teaching styles, techniques or organization. For example, you could evaluate the effectiveness of adding a comprehensive class project to the course by determining if it improves the knowledge of the students in areas that are considered critical to the course.

**Conclusion**

The development of the new Civil Engineering program at the University of Minnesota Duluth is a unique opportunity to evaluate the current methodology and curriculum of engineering education. UMD has decided to emphasize practical knowledge as well as sustainability while designing their curriculum. The program has approximately 65 students in each class (currently freshman, sophomores, and juniors), which is significantly higher than the 25 that was initially estimated, indicated that there is potential interest in such a program from students. A very active industrial advisory board continues to state that the industry is interested in graduates from the program. An integrated assessment system is in place to identify any weaknesses in the program that need further examination. All of initial steps to create a successful Civil Engineering program have been completed, and the authors are confident that this new program will continue to succeed.

**References**


Surviving ABET assessment and still having time to grow your engineering program:
Keeping the focus on the students

Lance D. Yarbrough, Scott F. Korom and Zhengwen Zeng
University of North Dakota, Department of Geology and Geological Engineering

ABSTRACT

Our recent ABET compliance review, the extensive training, and the transformation of our program has given us a number of ideas. We found that efforts focused on the frontend provided benefits in the form of reduced stress in the long-term (3–5 years). Next, worked with a subset of our constituency to establish few and simple-to-assess program educational objectives. Further, we staggered our assessment cycle in order to reduce assessment data collection, yet increase the usefulness in the evaluation process. We have eagerly incorporated the updated ABET view of multidisciplinary teams, which until recently was unknown to us.

INTRODUCTION

The Geological Engineering program at The University of North Dakota has recently finished an ABET compliancy review. As a relatively small engineering program in numbers of both faculty and students, we would like to share our experience and lessons learned and posit their relevance to any size program. We found it best to have a well-thought-out scalable assessment plan that properly samples cohorts at a summative learning point without duplication. In practice, recently trained faculty were easier to convince of the need for a streamlined assessment plan and processes. Because we found that a single ABET-knowledgeable individual in the program will have a difficult time convincing colleagues of the importance of assessment, we suggest that at least two faculty trained in assessment are necessary for the program’s continued growth. ABET accreditation is needed to attract new students, yet the work required to retain that accreditation can certainly seem overwhelming. The “death by assessment” mantra might begin to ring in one’s ears. However, it does not have to completely consume your time. With proper training and a willing set of faculty, you can offer a growing, improving program, while providing students an enriched engineering education.

HOW DID WE VIEW ASSESSMENT?

The satisfaction of ABET requirements were the program faculty’s first thoughts when faced with assessment and planning. Our next challenge was to fully determine the ABET criteria and how to assess that criteria in our program.

The Venn diagram in Figure 1 is an attempt to characterize our idea about assessment as it pertains to ABET. ABET tends to be the brute in the room that is continually getting your
attention. That brute leaves little time to assemble a proper Assessment Plan for your department or program. Even the ongoing course and teaching assessment are compressed and compete for your time. Again the diagram points to important questions about your views on assessment. One might ask the following: Does my degree program really have an assessment plan or do we just pile paper during the 5th year of the ABET cycle?

We could continue to comment about how this view of assessment impacts one’s career, research time, and tenure, but the focus of this discussion is on students. How does this view impact your students? Have students been provided with enough feedback to improve their skills and judgment? One might realize their course assessment seems a bit weak. Is that because only course grades have been used to assess the program? Are you taking an honest look at your degree program or do you equate your program assessment with everything ABET?

As we understand it, this is the unfortunate view typically taken by those who are tasked with administering a department’s program assessment. In our case, our Dean and Chair were supportive of the need for training and resources. We found that though we were trained, the remainder of the faculty were not necessarily appreciative of our efforts and continued to view assessment as a nuisance that must be tolerated until fed just enough so it goes away until the next cycle.

Two of our original misconceptions about ABET and its uses are shown in Figure 1. First, we presumed program assessment was entirely ABET. We were quick to discover that the assessment of our degree program can be robust, but ABET offers the framework that has become the standard. Any plan can be used for assessment, as long as you can map back to each of the ABET criteria. So why not just use the given criteria and focus on the students? Secondly, course assessment was thought to be an important component of program assessment process. Again, we quickly learned that an over reliance on individual student grades is not a proper form of program assessment and will lead to a shortcoming during your next ABET review.

Figure 1 – An illustration of a possible ill-conceived idea of assessment that is all too typical for engineering programs. ABET seems to dominate, if not make up the entire domain of the assessment plan. It may even dominate the view of assessment such that the only plan is to satisfy ABET.

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**How Can a Paradigm Change Help in Assessment?**

In contrast, Figure 2 illustrates a change in our paradigm of engineering program assessment. It is a more balanced view of the components of an Assessment Plan that puts ABET in its proper place, which is entirely within the domain of program assessment. Essentially, ABET is no longer the brute. By starting with an assessment plan that enviably is laden with ABET terms and processes, the mental picture is one of a much smaller, diminutive, and less dominating part of the overall plan. Again, we have little doubt that the majority of program assessments will be dominated by ABET criteria and language, but we believe keeping the perspective like that in Figure 2 will lead to less stress and more opportunities to simplify assessment plans. It is possible with our posited simplified view that more of a department’s faculty will become supportive, thus creating a culture of streamlined, targeted, assessment that satisfies many users of the data.

![Figure 2](image)

*Figure 2 – An illustration of a more balanced view of a department’s assessment. ABET should be thought of nothing more than a component of the program assessment and course assessment as an extension of program assessment.*

Course assessment and ABET assessment requirements do not intersect in our paradigm. But this is not to say the student work used for the course grade is not the same used in assessing the program. It is important to realize that the same paper or test problem can be used in both! Simply use a different assessment tool on each. The goal of producing better students includes a well-balanced assessment plan. Not an *ad hoc* policy.

Note that we have increased the prominence of teaching assessment in our view of the ENTIRE assessment plan. This may be wishful thinking on our part but it is a necessary part of assessment. While it is important to streamline an assessment, the hasty use of a single assessment opportunity to collect data for several assessment reports may, in fact, be counterproductive. Many universities use student-based evaluation forms as an indirect assessment of teaching, as well as to assess class materials and perceived goals. This is an important point to make while including teaching assessments in assessment tools designed to be used with overall program assessment. We found that we were more likely to get faculty...

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participation in the assessment plan by decoupling the assessment tools involving teaching and program assessment. Key players are likely to have more buy-in while collecting the required data if they understand that the data will not, in some way, compromise their efforts.

Buy-in from the faculty is a must. It is important to develop a culture of assessment that is student focused. We recommend making a plan that fits the available resources of a department’s program, and making it as integrated as possible with other ongoing assessments in the program (i.e., course assessment). Know specific modules in particular courses that offer a summative assessment opportunity and work with those instructors to have the student work evaluated for program assessment at the same time it is assessed for student performance in the course. This simplifies the program assessment immensely.

**NEW IDEAS HAVE HELPED CHANGE THE CULTURE**

With this new paradigm of assessment now providing a new perspective, we wish to provide a few ideas and processes that have helped us keep focused, while providing students with a fulfilling educational experience.

1. Set up a grid to delegate the assessment data collection. A transparent method of what is collected, WHEN and by WHOM, is critical to a successful program assessment. As new faculty come in they will already know the plan and have opportunities to ask questions prior to data collection. Also, the grid provides a method of accountability for all faculty in the assessment plan.

2. Incorporate assessment participation as a requirement for tenure and promotion.

3. Get into the habit of copious note-taking at meetings involving curriculum issues. Be sure to record the reasons why actions were taken and provide a short narrative background to the decision. Feel free to repeat the condensed record of the discussion each time the topic is revisited in subsequent meetings. The few extra paragraphs may seem redundant, but it helps to focus discussions during future meetings, reminds faculty of reasons why the decision was made (memories are short and faculty move on), and provides a fantastic resource when compiling evidence for ABET Criterion 4 (Continual Improvement).

4. Be sure to identify the faculty in the program! We were under the impression that faculty in the department were the faculty in the program. This is a very dangerous assumption. If you do not define your program faculty, the ABET Program Evaluator will do it when the team arrives at your campus and their assumptions may be to include or exclude faculty who have nothing to do with your program. We have 11 full-time faculty in a multi-disciplinary department and only 4 have been identified as the program faculty for the engineering degree program. We go a step further and identify the membership of the Geological Engineering Curriculum Committee (GECC) as the program faculty. In theory, any faculty member of the School or University can be a member of the GECC. In practice, it is a subset of the department faculty. This arrangement may be advantageous to other multi-disciplinary departments, which are becoming more common in these economic tough times. By limiting the program faculty to only those who wish to participate in the degree program, you have several benefits: 1) those individuals who make the effort to be part of the program faculty tend to have more buy-in to the success of the program, 2) for the purpose of satisfying Criterion 5 (faculty), the program needs only to provide information about those individuals in the program faculty and not the
entirety of the department, 3) smaller group dynamics tend to be more productive and focused, 4) similar to the last point, a focused group dealing with curricular issues can take on a more expanded role and manage the entire degree program. There is no minimum number of faculty specified by ABET.

5. Always remember that ABET is an assessment of the program, not of individual students or the department. Also, a student in the program should only be assessed once per performance criteria. If your assessment plan includes formative assessment opportunities, these should be listed separately from summative data when used for ABET evaluations.

6. “Multi-disciplinary” may not mean what you think. ABET does not have an official definition. However, there are guidelines that have come from Dr. Dayne Aldridge, Accreditation Director for Engineering (Aldridge and Lewis, 1997). Dr. Aldridge was asked for the ABET definition of multidisciplinary teams as used in Criterion 3. His response provides two definitions that may be used depending on a program’s needs. First, programs and an engineering school can work together to provide students with different specialized knowledge and skills to contribute to the team. So civil engineers and mechanical engineers can work together augmenting each other’s design experience. This approach requires extensive coordination between programs or departments. Second, a multidisciplinary team may be more appropriate to smaller-sized programs. This definition requires team members to assume the role of specialists during the design project. For example, a geological engineering design challenge may have individual members becoming the group expert for fundamental areas such as groundwater, rock mechanics, soil mechanics or environmental components of the design. ABET requires programs to document protocols to select roles for team members and to assure team members worked as specialists in the area chosen. It should be noted that programs using the specialist team member roles must be sure they distinguish the design challenge from a typical student work group experience. To be sure roles are followed and assessed, the selection of these roles should not be left to the students. Clear designation of the roles is needed so that students can make special or unique contributions to the teams’ purpose.

TRAINING IS CRITICAL TO A SUCCESSFUL ASSESSMENT PLAN

We recommend that a program have at least two faculty members who have had recent training in ABET assessment (Rogers, 2009). This is not to pay homage to the old saw “misery loves company” but does offer a distinct advantage to the success of assessment in your program. If one individual is trained and (unfortunately) becomes the life of the assessment, then that energy is gone when that particular person moves on or becomes disinterested in the process. A second person offers the first a sounding board and confidant(e), of sorts, to help advance the program assessment to a department-wide effort.

Ideally, all program faculty should attend a training seminar about assessment. These can be with school, university, or national organizations. ABET offers many opportunities, from an intense one-day fly-in workshop to the 5-day Institute for the Development of Excellence in Assessment Leadership (IDEAL) workshop.
SUMMARY

The intent of this paper is to encourage faculty to begin early in the accreditation cycle to evaluate their program and to begin collecting assessment data. From time to time, it is a good practice to step back and evaluate the success of a program, and satisfying ABET criteria is a requirement for a successful and healthy program.

REFERENCES


BIOGRAPHICAL INFORMATION

LANCE D. YARBROUGH, Ph.D., P.E., is an Assistant Professor in the Geology and Geological Engineering Department at The University of North Dakota. He is a member of the department’s assessment committee and is a 2010 ABET IDEAL scholar. He is licensed in Mississippi as both a Professional Engineer and a Registered Professional Geologist.

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ZHENGWEN ZENG, Ph.D., is an Assistant Professor in Geology and Geological Engineering Department at The University of North Dakota. He is a member of the geological Engineering Curriculum Committee and the GGE Committee for ABET Assessment, was trained for ABET’s “Sustainable Assessment Process.”

1.
Fuzzy Logic on an FPGA

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An Introduction to Fuzzy Logic:

At first glance, the words “fuzzy logic” may seem to imply an incoherent and non-concrete thought process. It sounds like it ought to be imprecise and not terribly useful. However, when we take a look at what it's actually doing, it becomes clear that fuzzy logic is a useful tool for making better decisions and modeling real-world influences.

In traditional binary logic, everything must be sorted into discrete categories. Either a value does or does not fit into given criteria. It doesn't allow exceptions for edge cases, or really have much of a way to handle them. And in many cases the distinction made is a relatively arbitrary one. For example, take a look at the way BMI categories are distinguished in the medical field. A woman who measures 5'5” in height is considered to be obese if she weighs 180 pounds. However, if this same woman is even half a pound lighter, she falls into the overweight category. A human doctor making health evaluations based on weight would be able to say that that half a pound doesn't really make much of a difference. A computer program using traditional logic would be unable to make that decision, but with the application of fuzzy logic, it could be accommodated.

Fuzzy logic has been used in a variety of different applications, including medical applications, as well as many other useful functions, including auto-focus in cameras, temperature control systems, anti-lock brake systems, travel time estimates, and genetic trait predictions. And these are just a small portion of the ways that fuzzy logic is already being used. As it becomes more and more commonly used, it would make sense for it to be desirable for students to have an understanding of the low-level
Functionality of fuzzy logic.

Field Programmable Gate Arrays and Modeling Logic:

When studying computer architecture, it is useful to be able to model and simulate designs, because it is not always practical to construct it using discrete components in a laboratory, nor is it time or cost-effective to produce a testable silicon wafer design, especially as students are only developing an understanding of the material. As such, modeling is a useful way to incorporate an interactive understanding of architecture design.

One good way to accomplish this is through the use of an FPGA or field-programmable gate array. An FPGA is an integrated circuit that can be programmed to have its functionality changed. This makes it useful for modeling and testing architecture design, as the series of logic gates can be programmed to emulate a wide variety of digital designs, limited by the number of gates available, and the reprogrammability allows for making and correcting of mistakes in a way that creating an integrated circuit does not.

An Overview of the BASYS Board:

The BASYS board by Digilent was used for this project. It contains the Xilinx Spartan 3E chip, and provides a variety of input and output devices, including 8 switches, 4 buttons, 8 LEDs, 4 7-segment displays, and an onboard variable oscillator, among a few other sources of input and output. This wide selection of integrated functionality makes it a useful tool for studying a wide variety of basic designs, an example of which is detailed in the remainder of the paper. The BASYS board is pictured below in Figure 1.
The oscillator on the board can run at multiple frequencies, and this can be controlled through the use of jumpers on the board. The available frequencies are 25, 50, and 100MHz. The actual frequency used has little bearing on this example beyond how smoothly the 7-segment displays cycle. However, in other applications, this may not be the case.

This example makes use of the BASYS's switches as numerical input, buttons as function selection input, LEDs as real-time numerical representation, 7-segment displays as function output, and oscillator as a clock.

A complete list of the pin assignments for the BASYS board can be found in Figure 2.
Example of a Design:

The goal of this example is not only to implement, but also to demonstrate the implementation of two fuzzy logic instructions. Specifically, fuzzy AND and fuzzy OR.

In order to accomplish this, I have programmed the FPGA in the BASYS board as a finite state machine running through a sequence of taking numerical inputs, and processing them according to the function selected by the user. In the initial state, the user enters a number on the switches, loads it into a latch, enters a second number on the switches, and presses a button to select what function should be performed on the two numbers. The resulting number is then stored in the latch to be used as part of the next calculation. The process can be visualized in the flowchart pictured in Figure 3, below.
In order to implement this, the design is split up into several functional parts. There are, naturally the implementations of the instructions themselves. Each of these has its own description. In addition to that, the interface and finite state machine also needed to be implemented. The finite state machine is also its own description, and is the core of the project's overall design. The implementation also includes a binary to BCD decoder, a BCD to 7-segment decoder, and a visual multiplexor to allow the 7-segment display to be used as a 4-character output.

In addition to these structures, there is also functionality encoded into the interface itself. For instance, the input on the switches is always reflected on the LEDs, in addition to always being one source of numerical input. On top of this, the numerical value in the latch is constantly being processed to be displayed on the 7-segment array.

These pieces of the design are all put together, along with assigning all the inputs and outputs, in the main section of the Verilog code. The switches are fed to the output LEDs, as well as to the input of

Figure 3: Finite State Machine Flowchart
the FSM. The FSM also takes input from the oscillator and buttons, and outputs to the working register latch. The working register latch functions as an input to the binary to BCD decoder, which outputs directly to three BCD to 7-segment converters, the outputs of which are connected to the visual multiplexor, which outputs to the 7-segment display selector bits as well as to the segments themselves.

**Main I/O Body**

```verilog
module main(  
    input [7:0] switches,  
    input [3:0] buttons,  
    input clock,  
    output [7:0] leds,  
    output [7:0] segments,  
    output [3:0] disp_select  
);  

    wire [3:0] b0, b1, b2, b3; //intermediate BCD numbers  
    wire [7:0] W; //working register  
    wire [7:0] d0, d1, d2, d3; //intermediate Display digits  

    assign leds = switches;  

    Bin2BCD conv1(W, b0, b1, b2, b3);  
    BCD2SevSeg c0(b0, d0);  
    BCD2SevSeg c1(b1, d1);  
    BCD2SevSeg c2(b2, d2);  
    BCD2SevSeg c3(b3, d3);  
    SevSegMux mux1(d0, d1, d2, d3, segments, disp_select, clock);  
    FSM mach1(switches,  

```

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buttons,
clock,
W);
endmodule

The completed design runs on the BASYS board, and demonstrates the basic functionality of “fuzzy and” and “fuzzy or”. Images of the design running can be seen below in the following two figures.

Figure 4: Fuzzy And Chooses Between 113 and 81

Figure 5: Fuzzy Or Chooses Between 106 and 210

Conclusions:

Basic fuzzy logic instructions are useful for many applications, and relatively simple to implement. The use of an FPGA board assisted in making this process both easier to comprehend as well as allowing the implementation to be easily demonstrated to other people. This design process is not only useful in
understanding the example given here, but also as part of a larger approach to learning and understanding digital design in general.

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Resources:


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