Successfully Building Bridges Between Education and Engineering Programs at a 4-year Comprehensive University

Jason Thrun and Philip Parker
University of Wisconsin-Platteville

Abstract

Six faculty members (three from engineering, one from mathematics, and two from education) teamed up to plan and implement an innovative project. During the fall semester of 2004, nine pre-service teachers in secondary- and middle-level mathematics education enrolled in an experimental section of GE 1030 – Introduction to Engineering Projects, an existing 1-credit hour class that is required for all engineering majors, and is typically taken in the freshman year.

The project designers' decision to open an experimental section of GE 1030 to education majors was motivated by the idea that an experimental section of GE 1030 could benefit future teachers of mathematics and science and could also benefit the field of engineering. Specifically, participating in an introductory engineering course could provide the pre-service teachers with some resources to create lesson materials that could enhance their future teaching (by their ability to develop mathematical ideas via engineering). Additionally, these education majors could gain valuable insights into the field of engineering that could help them inform their future students on the excitement of the field of engineering.

This paper provides details on the experimental section of GE 1030 and identifies the primary goals of the project. This paper also discusses the formative assessment process and preliminary results. In particular, the authors present some major findings in terms of the comparison between the student populations, the benefit of the course for the pre-service teachers, and insights for future projects.

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Introduction

Faculty members from the Engineering Department, School of Education, and Mathematics Department at the University of Wisconsin-Platteville teamed up to design and implement a multidisciplinary project. A fundamental component of the project was to design an experimental section of GE 1030 – Introduction to Engineering Projects that would be taken by both engineering and education majors. This highlights one of the most innovative aspects of the project: using an existing course (rather than creating an entirely new course) will make eventual implementation much easier. Pre-service teachers enrolled in the experimental section also were required to attend bi-weekly seminars, as will be explained in more detail in subsequent sections of this paper.

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GE 1030 is a 1-credit hour class in which student complete engineering projects. The projects are all interdisciplinary. Tree sections are typically offered in the Spring and 9 – 12 sections are offered in the Fall. The sections are capped at 40 students. The projects completed by the experimental section are typical of the projects completed in all sections: thermodynamic efficiency of an electric teakettle; investigation of engineering materials through design and testing of a concrete mix; computer programming with Lego Mindstorms. Dr. Parker, the project director taught the experimental section of GE 1030. Dr. Parker attempted to model active learning techniques, and used a variety of hands-on activities, group discussions, physical models, etc. A syllabus for the experimental section is provided in the appendix.

As designed, this project has both global and local goals. The global goals are far reaching and aim at promoting engineering as a profession. The local goals are more immediate and focus on the affect of the project on the faculty and the pre-service teachers.

In a global sense, the project promotes technological literacy. Few would argue the importance of a society that is technology literate, so opening a section of GE 1030 to non-engineering majors seems both worthy and appropriate. However, the project designers had a vision for the project that would reach beyond the specific non-engineering majors who would be enrolled in the class. Because the non-engineering majors would be pre-service teachers, their experiences in this introductory course could potentially affect their future teaching. Moreover, through their experiences in the course, these future teachers could gain some insights into the engineering profession that could help them advise their future students who might be interested in engineering. In this sense, this project has the potential to:

- further develop the pre-service teacher's technology literacy and therefore the technology literacy of their future students and
- further develop the pre-service teacher's understanding of engineering as a profession and thereby promote engineering as a desirable career for their future students.

This project also has some significant local goals. One such goal is collaboration between engineering and education faculty. Such collaboration could help faculty members develop resources outside their fields of expertise and foster appreciation for a less familiar discipline. Since faculty at universities can become departmentalized, this idea has merit in its own right. However, this collaboration with education faculty has the potential to improve the teaching of engineering. Similarly, the collaboration with engineers provides opportunities for education faculty to see mathematics and science through the eyes of engineers. In an analogous way, the pre-service teachers' exposure to the engineering profession may change their attitudes about engineers and the profession of engineering.

Perhaps the most important local goals relate to the pre-service teacher participants. This project has the potential to provide the participants special opportunities to see applications of mathematics and science that might not otherwise be available. This exposure to the applied nature of mathematics and science has the potential to further develop these pre-service teachers' understanding of mathematics and science and their ability to teach these disciplines. As the reader will find in the section on methodology, all the participants chosen for this project were pre-service mathematics teachers. Consequently, the authors will narrow the focus of the remaining goals to issues relating to mathematics education.

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As stated by the National Council of Teachers of Mathematics (NCTM) in the *Principles and Standards for School Mathematics*[1], "To be effective, teachers must know and understand deeply the mathematics they are teaching and be able to draw on that knowledge with flexibility in the teaching tasks." Although this seems very reasonable, if not obvious, there is some ambiguity in this statement. What does understanding mathematics entail? Researchers[2,3] suggest that understanding mathematics means understanding mathematics facts and procedures but also understanding relationally or conceptually. As noted by Mewborn[4], teachers generally have strong procedural skills but may lack this conceptual understanding. Through this GE 1030 course, students have the opportunity to deepen their conceptual understanding of mathematics and science through the project-based approach.

While it necessary for teachers to deeply understand the mathematics they are teaching, this is certainly not sufficient. In addition to content knowledge, the NCTM's *Principles and Standards for School Mathematics*, suggests that teachers must also know and understand students as learners, and must know and understand pedagogical strategies. Continuing, the NCTM further suggests that a teacher must create a challenging and supportive classroom environment. This is certainly a lofty goal. Because of the nature of GE 1030, the students in this class are active learners. The course is demanding, but he instructor offers appropriate guidance. Consequently, the authors of this paper feel that the GE 1030 course provides a setting where these future teachers can experience a model of teaching and learning that is consistent with the recommendations made by the NCTM. More specifically, the pre-service teacher participants in this project learn in a classroom environment in which active learning techniques are modeled for them. This is precisely the environment they will need to generate in their future classrooms.

In the remainder of this paper, the authors will describe the general methodology used in the project, including the assessment plan, and will identify some major preliminary findings of the project. Because of the nature of the global goals already outlined, they will not be addressed.

Methodology

In the spring of 2004, faculty members from the Engineering Department, School of Education, and Mathematics Department teamed to design the general project and an experimental section of GE 1030. To meet the goals as outlined in the introduction, the faculty envisioned a project that would provide pre-service teachers an opportunity to take an introductory engineering course. More details concerning the selection of students, the summer discussion and planning sessions, the modified introductory engineering course, and the assessment plan are provided in the companion conference paper and in the following sections.

Nine education majors applied for admission to the project, all of whom were selected to participate. All the project directors were impressed by the commitment reflected in the one-page application letter. Table 1 identifies the gender and major of the participants.

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Table 1: Student Participants

	Female	Male
Elementary/Middle Mathematics Education Majors	2	0
Secondary Mathematics Education Majors	3	4

Although the original plan was to work with pre-service mathematics and science teachers, only pre-service mathematics teachers applied. Because all of the participants would be future mathematics teachers, the project designers could focus specifically on issues related to the teaching of mathematics. With this in mind, the faculty began planning the experimental section of GE 1030.

In the summer of 2004, the six faculty members met twice a week to focus on two main issues – one that is primarily theoretical and one that is primarily applied. In order to work collaboratively, the engineering faculty needed to understand perspectives of the education faculty and vise versa. More specifically, the faculty members needed to become familiar the other faculty members' disciplines. To this end, the group held "Discussion Circles" where relevant, research-based articles were discussed. Articles focused on technological literacy, engineering ethics, multiple intelligences, engineering, science, and mathematics standards for middle school and high school students, and general issues related to the theory of teaching and learning.

The applied component of the summer planning was to take a collective understanding of engineering and education and plan an experimental section of GE 1030 that would meet the goals as outlined in the introduction. The faculty met weekly to plan this experimental section. In particular, the faculty designed a course that met the needs of the future engineers but would also take advantage of the population of education majors. Little attention was paid to the course content as one of the keys to the success of this project is to use an existing course "as is."

In many ways, this experimental section of GE 1030 looked like any other section. For the most part, the education majors worked on the same projects and took the same exams as their engineering counterparts. In an attempt to make the course more meaningful for the education majors and to provide continuous assessment of the project, the coordinators created a one-hour, biweekly seminar for the education majors. This seminar would be held outside of regular class time and would be lead by a faculty member from the School of Education. The designers of the project anticipated that in these biweekly seminars, students could discuss activities from the GE 1030 course and how the material might relate to their future teaching. Students could also discuss their difficulties and concerns with the engineering nature of the course. A summary of topics for the seminars is given in Table 2.

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Table 2: Biweekly Seminar Topics

Meeting Date	Topics
September 1 – Before Classes Start	Introduction Expectations Schedules
September 16	Applying this course to future teaching Why pre-service teachers should know something about engineering
September 30	Applying this course to future teaching Importance of projects in K-12 setting Difference between education and engineering students
October 14	Final lesson plan Mathematics standards in K-12
October 28	Mathematics standards in K-12 continued
November 11	Multiple Intelligences
December 2	Final summative journal assigned Future of the course
December 9	Final lesson plans presented

The designers also planned to use these bi-weekly seminars to discuss the students' final project – a lesson plan that they could use in either middle school or high school. As described to the education majors, the lesson plan had to use a project-based, engineering activity to address a mathematical concept. The education majors were also instructed to justify the value of their project using state or national standards for the teaching and learning of mathematics. Because the education majors were asked to design a lesson plan, they were not required to submit a research project for the course. In addition to attending the bi-weekly seminar, this lesson plan was the only significant difference between the expectations of the education majors and the expectations of the engineering majors.

In addition to designing a course that would maximize the benefit to the education majors, the faculty also needed to plan how the assess the value of the project. Although some of the assessment would come from surveys, the faculty anticipated that the most useful forms of assessment would come from the biweekly seminars, the students' weekly journals, and the final lesson plan. Table 3 shows a summary of the assessment items and when they were administered.

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Table 3: Assessment Techniques

First Week(s) of Fall 2004 Semester	Engineering Attitudes Survey – Given to ALL students in GE 1030 (all sections) and selected students in one class for middle-level math/science education or science majors
	Learning Style Assessment – Given to all students in pilot section of GE 103 Section 1 and faculty participants
	Technological/Engineering Literacy Instrument – Given to pilot section of GE 1030
	Phone Questionnaire – Given to those education students that chose NOT to participate
	Discussion at first meeting regarding the motivation for education majors to participate in pilot project
Continuous Assessment during the Semester	Discussions at each bi-weekly meeting
	Weekly journals
	Projects presented as part of GE 1030 requirements
End of Fall 2004 Semester	Evaluation of unit plan/lesson plans and ability to connect to state academic standards.
	Engineering Attitudes Survey – Given to students in the pilot section of GE 1030
	GE 1030 Final Exam
Post – Fall 2004 Semester	Journals
	Plans for BEE participants to participate in Professional Conferences/Presentations
	Follow pre-service teachers into student teaching – did they incorporate the lesson plans into their teaching

Major Findings

The authors are not yet able to provide complete analysis of the project as the course recently ended. However, some preliminary findings are presented. The findings are organized in three categories. One is a general comparison of the engineering students and education students in the pilot section. A second category relates to the value of the project in terms of the benefit to these future teachers. A final category relates to what the project designers learned that could affect future projects.

At the planning stage, the faculty members were concerned about how comfortable the education majors would feel in an introductory engineering course. Would they be intimidated? Would upper level students be offended to be in an introductory class with freshmen? How would the education majors interact with the engineering majors? The journal entries, weekly seminars, and class work help answer these questions.

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After a few weeks, it was evident that education majors had assimilated well. Although some education students had some initial concerns about being in an engineering class, as evidenced in some of their early journals, their seminar discussions indicated they all became comfortable in the class. Moreover, many of the students expressed great excitement to be in the class.

The issue of mixing upper-level students with freshmen in an introductory course was never an issue. While sections of GE 1030 are generally composed of freshmen engineering majors, this particular section had an unusually high percentage of transfer students. Upon further reflection, the authors do not think the difference in academic maturity would have been an issue even under more typical circumstances. After all, the education majors volunteered to participate in the project.

Figures 1 and 2 show the comparison of students in terms of the final exam score and the final course grade. Overall, the pre-service teachers performed very well in the course. It is important to remember that the pre-service teachers were recruited and self-selected. Consequently, these students were already known to be motivated and interested in the project.

Although Figures 1 and 2 do not show any significant difference in the quality of work between the education majors and the engineering majors, observations revealed that the education majors did appear to be more comfortable in certain settings. For example, the education majors more willingly accepted a leadership role in the group projects and were more comfortable giving oral presentations.

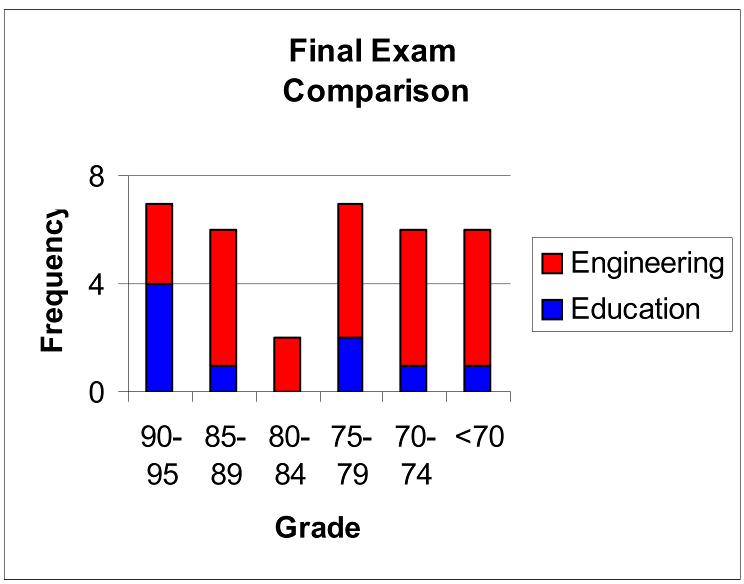

Figure 1: Comparison of final exam scores.

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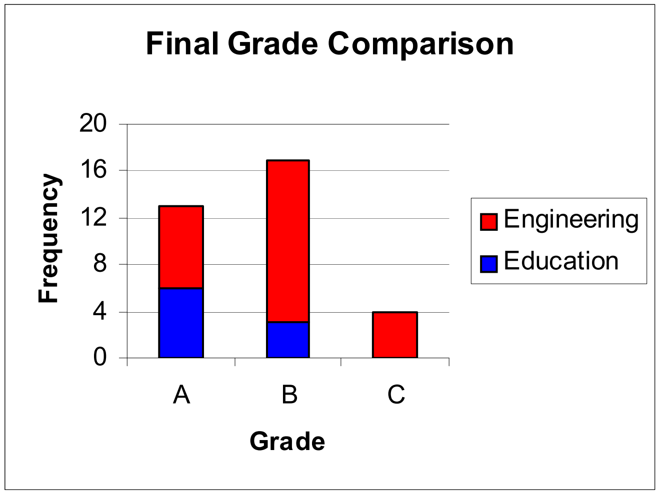

Figure 2: Comparison of final course grades.

It is not an exaggeration to state that the education majors loved the course. This was evidenced in their journals, their attitudes in class, their attendance, the quality of their work, and the seminar observations. In fact, several participants suggested that all pre-service mathematics and science teachers should take GE 1030. This statement was not made without a caveat. The pre-service teachers valued the biweekly seminar so much that they suggested making a modified 2-credit version of GE 1030 for education majors. The participants indicated that the real value of the project came from coupling the introductory engineering course with the in-depth seminar because in the seminar, students had the opportunity to discuss how they could apply the engineering to their future teaching.

Why was the biweekly seminar so important to these students? Yes, the students were given an opportunity to talk about how they could use engineering to present mathematical ideas, but what became evident was the absence of this opportunity in other classes. These students were nearing the end of their course of study so they had taken many upper-level mathematics and education courses, but they had very few opportunities to link the two. This course provided an additional opportunity that these students craved.

Findings for Future Projects

Some of the findings that may affect future projects are more or less restatements of the findings already presented. Because the authors of this paper consider these findings significant, they are repeated from a different perspective.

If this project is to continue with pre-service teachers, it is important to have the biweekly seminars. The participants valued these seminars because this is where they were able take the engineering applications presented in class and work them into a conceptual framework for future teaching. "Throwing" education students into an introductory engineering course without this component would probably not be as successful.

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Throughout the semester, the project designers increasingly valued the student journals. This was, in part, because the journals provided a means to assess the value of the course. A more important function of the journal was to drive the discussion of topics at the next seminar. The participants, however, voiced some initial concerns about the journals. Some of the students felt the weekly journal was busy work. To help improve the negative opinion, the project directors emphasized the function and value of the journals. After a few weeks, the students realized that the ideas raised in the journals drove the seminar discussions. After these initial rumblings over the journal process, there was no further evidence of dissatisfaction. In fact, all the pre-service education majors continued to submit high quality reflective journals.

Some of the faculty members underestimated the difficulty that students would have in creating a lesson plan that used engineering to address a specific mathematics concept and/or standard. Although every participant was able to create a lesson plan that embodied the spirit of the course, they had difficulty linking the project to a specific mathematics topic. That is, every participant was able to create a lesson plan that used some project-based activity, and every participant readily noted the problem-solving nature, but many of the students had significant difficulty linking the activity to a specific mathematics topic. If teachers are to use project-based learning in their future classes, they need to able to justify the value of the activity, and not in general terms. Teachers need to explain what specific content can be addressed in an activity.

Summary

The authors are not in a position to evaluate the project in terms of the original goals of the project. With time, the project developers will be able to sift through and analyze all of the data collected. However, from the data that was collected from the biweekly seminars, the project was valuable. The students appreciated the opportunity to be involved in this innovative project and their excitement was evident. From the perspective of the project designers, the project was rewarding. It was refreshing to see students involved beyond expectation. The class environment was greatly enhanced by the pre-service teachers' excitement and willingness to interact in lecture.

Acknowledgment

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Biographical Information

Dr. Philip Parker (parkerp@uwplatt.edu) is an Associate Professor at the University of Wisconsin-Platteville. He received his B.S, M.S., and Ph.D. from Clarkson University in Potsdam, NY. His teaching interests span the Environmental Engineering field. He is past Program Chair for the ASEE Environmental Engineering Division.

Dr. Jason Thrun (thrunj@uwplatt.edu) is an Associate Professor in the Mathematics Department at the University of Wisconsin-Platteville. He received his B.S from the University of Illinois and M.S. and Ph.D. from Northern Illinois University. In addition to other undergraduate courses, he teaches many courses for pre-service teachers preparing to teach elementary and middle school.

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Appendix

Lesson Plan

Each student is to develop a lesson plan for a project lesson. There is no specific length requirement. Make the plan as long as you need to complete the objectives. It should be part of a bigger unit plan.

Format

Unit Overview
Write an overview of the unit that the lesson will be included in. How will the lesson fit into the overall unit.

Materials
What materials will be needed to successfully complete your lesson?

Objectives
Lesson plan identifies the intended audience.

Lesson plan identifies specific (mathematics) content that will be addressed.

- Lesson plan identifies standards addressed.
- Lesson plan identifies the level of understanding expected (basic facts, analysis, application.) Think Bloom's Taxonomy

Body of the Lesson
Lesson plan has potential to engage all students.

- Lesson plan begins at an appropriate level yet challenges students.
- Lesson plan fosters active learning.
- Lesson plan fosters communication.

Lesson plan identifies the role of the teacher and the student throughout the lesson.

Lesson plan justifies activities.

Lesson plan provides and opportunity for students to reflect and synthesize the main ideas of the lesson (closure).

Assessment
Lesson plan includes opportunity for formal or informal assessment **throughout** lesson.

Lesson plan describes how the success of the lesson will be measured based on objectives. (I know that this lesson was successful if....)

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Comments on the Lesson Plan:

We don't have a particularly structured outline for a lesson plan. We basically look for three components. We want the lesson plan to identify and describe what the students are expected to learn, how these students will learn this, and how the teacher will know that the students learned what was expected. So basically, we look for objectives, a description of what will happen during the lesson, and an assessment plan.

For the objectives, we look to see that teacher identifies specific content objectives and couples these with a reference to some standard(s) - Wisconsin Model Academic Standard(s), National Council of Teachers of Mathematics Standard(s), or Massachusetts Technology Standard(s). In the body, we like the teacher to account for what will happen during the lesson. It's very important for teachers to reflect on their lessons, so we look for evidence of this. Hence, we look for explanations if not justifications in the lesson plan. If a teacher begins with some warm-up activity, we would like to know the reason for such an activity. Is the activity meant to get the students to focus on mathematics, review past material, or provide an intro to the activity of the day? We look for explanations for each part of the lesson. For the assessment part of the lesson plan, we don't necessarily look for formal assessment. We simply want the teacher to reflect on the evidence that would be necessary for the teacher to conclude that the objectives were satisfied.

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GE 1030 - Introduction to Engineering Projects
Fall 2004 – Section 1

Instructor

Dr. Philip Parker
131A Ottensman Hall
parkerp@uwplatt.edu
342-1235

Office Hours

Monday	1:30 – 2:30
Tuesday	8:00 – 11:30
Wednesday	1:30 – 2:30
Thursday	9:00 – 11:30;1:30 – 2:30
Friday	1:30 – 2:30

Course Objectives

In this course, you will:

- Develop your report writing skills
- Develop your oral presentation skills
- Apply your spreadsheet knowledge to real engineering problems
- Learn about and apply the Engineering Design Process
- Explore all engineering disciplines offered at UWP
- Enhance your teamwork skills

Grading Policy

The grading of the course will be on a letter grading scale based upon the following:

90-100%	A
80-89%	B
70-79%	C
60-69%	D
Below 60%	F

90%	Homework and In-Class assignments
10%	Final Exam

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Notes

1. Homework and reports are due *before* the start of a class period. Homework handed in after the start of class, but before the end of the period will incur a penalty of 25%. Any homework handed in after the end of class will not be accepted. There are no exceptions.
2. In some circumstances, you may receive an extension on homework if you see me *48 hours or more* before the homework is due.
3. Cheating will not be tolerated, and will result in disciplinary action. You are encouraged to work with other students when completing homework, but the work you hand in must be your own.
4. Homework that is not exceptionally neat will not be accepted and will result in a grade of 0.

Tentative Schedule

Week	Class Date	Topic/Activity
1	September 2	Introduction; Engineering Design Process
2	September 9	Materials in Engineering
3	September 16	Concrete Mix Design Lab
4	September 23	Considerations for Engineering Design
5	September 30	Concrete Testing Lab
6	October 7	Reverse Engineering Lab
7	October 14	Efficiency I Lab
8	October 21	Efficiency II Lab
9	October 28	Safety and Ergonomics
10	November 4	Work Day
11	November 11	Software Design/Development
12	November 18	Lego Mindstorms I
13	November 25	Thanksgiving
14	December 2	Lego Mindstorms II
15	December 9	Presentations

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