Integrating Education Students in the Assessment of Engineering Courses

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ABSTRACT

Most engineering educators have several engineering degrees and no education degrees. This situation leads to well-meaning instructors without the knowledge necessary to most effectively teach their students. Meanwhile, education students frequently lack opportunities to apply assessment techniques learned in their classes. A collaboration between engineering and education faculty and students has recently been initiated at the University of Arizona to address these disconnects.

This collaboration seeks to improve how engineering courses are taught and to improve the education of preservice teachers. A preservice teacher is a student learning how to be a K-12 teacher. The focus of this collaboration is the assessment of student learning in engineering courses (and the concurrent improvement of these courses). Preservice teachers conduct the assessment as part of their coursework. The preservice teachers are charged with (1) improving the assessment of student learning in an engineering course and (2) suggesting pedagogical changes to the engineering course based on their observations and the assessment results.

This collaboration was first implemented in fall 2003 with 6 preservice teachers assessing the first-year Introduction to Engineering course. The goal of the program is to benefit both engineering students through improvements of their classes and education students through a hands-on opportunity to learn about analytic assessment of students in science and math classes. In this paper, the structure of this collaboration is examined and lessons learned from the first semester of its implementation are discussed.

MOTIVATION

Most engineering educators are not adequately trained to rigorously assess student learning. Most preservice teachers (a preservice teacher is a student learning how to be a K-12 teacher), meanwhile, do not have the opportunity to apply outside of the classroom the assessment techniques they learn in class. In the collaboration presented in this paper, K-12 preservice teachers perform assessments on engineering students enrolled in a freshman engineering design class.

The primary purpose of this collaboration is two-fold:

1) to assess what engineering students are learning so as to improve the pedagogical techniques employed in the engineering class, and
2) to expose the preservice teachers to broadly applicable engineering content such as problem solving and design while they actively learn about performance assessment.

The freshman engineering class at the University of Arizona is a critical component of the foundation necessary for engineering students to learn and flourish in their later coursework, yet little is known about what students actually learn during their 15 weeks in the course. In the class, teaching is approached with a variety of techniques, including large lectures on broad topics, small classes involving technical material, team-based design projects, and classroom activities; the class therefore serves as an excellent case for K-12 preservice teachers to see and assess in practice the topics they have been addressing in their coursework.

CONTEXT

This work presented in this paper is unique largely due to the collaboration between the Colleges of Engineering and Education. In this section, the context for the collaboration is established.

Assessment of Student Learning in Introduction to Engineering

The engineering course focused on in this collaboration is ENGR 102, Introduction to Engineering, a class taken by approximately 800 students each year in 20 different sections. The five learning objectives of the course are that students should:

- **Learn how to use the design process** to meet expressed needs.
- Become **effective team members**.
- Become **effective communicators**.
- Create career plans & develop the personal management skills needed to become **self-reliant professionals**.
- Understand the fundamental principles that support learning and become **lifelong learners**

While the learning objectives are well established, student learning with respect to the objectives has never been measured across the entire class. Core elements of the course such as team-based design projects and multiple oral and written reports should address many of the objectives, but we are not completely sure what students know after the class that they did not before. In this work, student knowledge of how to use a design process to meet expressed needs is targeted for assessment. This objective was chosen primarily due to the importance of design in engineering: meeting needs is the fundamental role of engineers and they do so through applying principles of design. Furthermore, objectives relating to teamwork and communication are important, but only due to their role in facilitating engineering design (i.e., an engineer needs to know how to work on teams because teams are used in design).

Part of the complexity is that students work in teams in ENGR 102, so assessing changes in individual knowledge cannot be based directly on reports written by an entire team. Furthermore, each of the twenty sections has its own tests, thereby preventing the use of common tests without changing the structure of the course. While common questions could be used, difficulty with the

wide variability in grading among the twenty different faculty teaching this course each year effectively prohibits directly using grades on common questions to assess learning. While other educators have used common exams to assess the effectiveness of first year engineering courses, they rely on multiple choice questions in areas such as statics[2] as opposed to the open-ended questions necessary to assess effectively a student's knowledge of a topic as broad and adaptable as design.

From this context, an assessment strategy was created that centered on a student's ability to critique a proposed design process. The decision to include preservice teachers in the development and application of the assessment was made to 1) increase the quality of the assessment, 2) improve the preservice teachers' assessment skills and 3) explore how exposing preservice teachers to engineering coursework affects their attitudes toward using and their ability to use engineering concepts in K-12 education.

Assessment in the Training of Preservice Teachers

Preservice teachers are required to take the assessment course Ed P 357 "Educational assessment" that covers topics related to the use of assessment in the classroom. In this course they learn about the basis for assessment in the classroom, crafting and using classroom assessment, and interpreting and using standardized tests. They are also required to take Ed P 310 "Learning in the schools" where among the topics related to developmental and learning theories, they are taught a whole section in classroom management and assessment. Through these courses, preservice teachers learn about the basics of assessment[1]. They are required to complete homework assignments and have exams both during and at the end of the semester. Unfortunately, through these classes they do not have enough exercise in applying and using assessment in the classroom. Later in their program, preservice teachers may get partial experience in crafting and using assessment in the classroom during their student teaching in schools under the supervision of a teacher.

In the fall 2003 semester six honor students in the Ed P 310 course volunteered to participate in observing and using the assessment of engineering students as part of their honors coursework. The students had the opportunity to observe engineering classroom teaching (lecture and group work in small sections), and learned details about crafting and using an analytic rubric to assess engineering students' learning in the ENGR 102 course. Students had hands-on experience in grading short essay tests using the analytic rubric, and at the end of their coursework they wrote a feedback essay about their experience during the semester. This opportunity has given preservice teachers real practice in applying the knowledge from both the EDP 357 and EDP 310 courses that other preservice teachers do not have.

COLLABORATION STRUCTURE

During the first semester of this collaboration, an engineering faculty member, an education faculty member, and an education doctoral student led the research team. Six preservice teachers participated and there were approximately 550 students in the engineering course being studied (of which 254 signed the human subjects consent form). The research team established the strategy for assessing the engineering course by running a pilot assessment in the preceding semester. This strategy includes a pretest, a posttest, and a survey. The scoring of the pre and posttests require a rater to apply a detailed analytic scoring rubric for measuring a student's

engineering design knowledge. Over the semester, the preservice teachers were trained to score the pretests.

The joint assessment effort is shown graphically in Figure 1. The top chart indicates when each pretest, posttest, and survey was taken by the engineering students. The bottom chart is more representative of the overall structure of the collaboration.

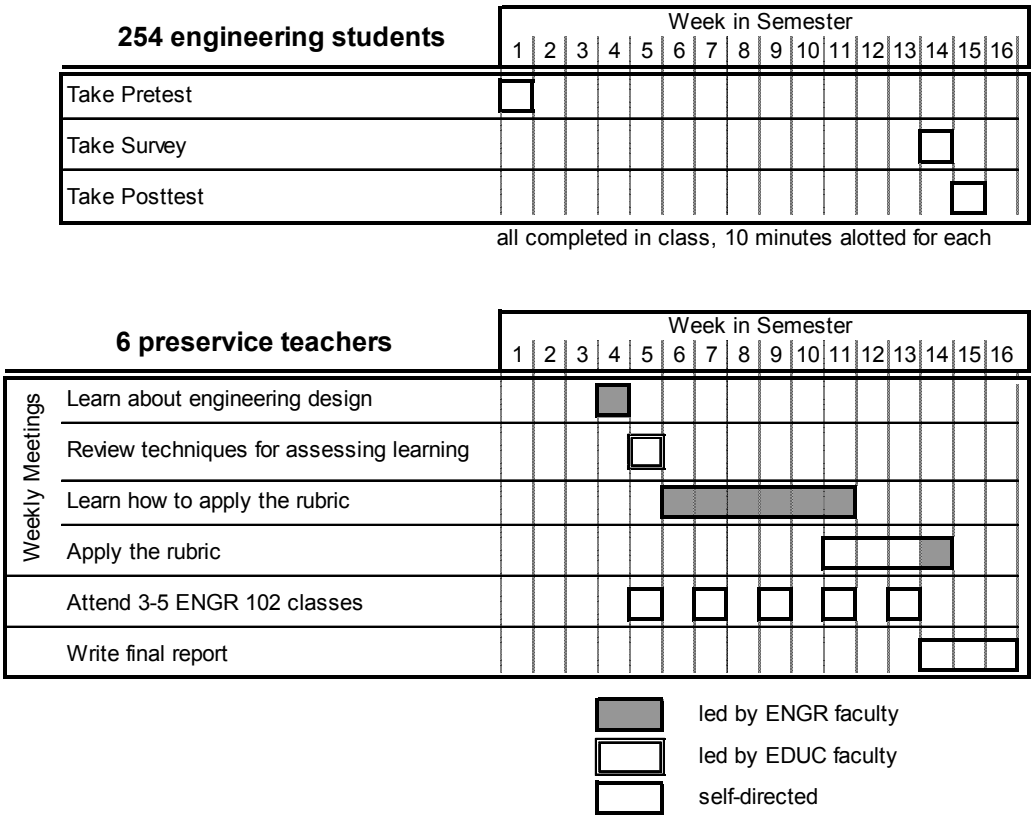

Figure 1 Timeline

The preservice teachers were participating to earn honors credit in a required class. They met with the research team once each week. Early in the term, these meetings focused on general issues such as learning about the engineering course and about the assessment of learning. After covering these basics, the preservice teachers were trained in using the specific rubric for the pretest. The process for teaching them the analytic rubric, which contained engineering-specific knowledge about design that the preservice teachers had not studied before, focused on using dialogue and consensus building. It involved the following steps.

1. showing several engineering student responses to the preservice teachers and explaining how to score them
2. jointly scoring engineering student responses as a group with the engineering faculty member leading the discussion
3. having each preservice teacher independently score the same 5 responses and then discuss the areas where the scores did not match

4. having the preservice teachers break into groups of three in which they scored 20 responses and debated disagreements in scoring as a team without a professor leading the discussion.

This iterative approach to training the preservice teachers moved gradually from *showing* them the rubric to having them *apply* the rubric themselves, with the reliance on faculty diminishing with each step.

In addition to their use in training the preservice teachers, these activities also led to many improvements in the analytic rubric. The preservice teachers were directly involved in the development of the analytic rubric while they were being trained to apply it. After the last step in their training, it was clear that the preservice teachers were scoring students' responses similarly to each other and to the research team members. Even though students reported a better understanding in using a scoring rubric, results of their scoring show that students may need more practice in order to increase the reliability of their scoring. For example, intra-rater agreement for the second author was above .95 but for the most experienced student rater was only .83. Inter-rater agreement coefficients for the student and author ranged from .80 to .86, numbers that should improve when the student raters are more consistent in scoring.

An interesting aspect of the collaboration is the focus on using faculty to teach other faculty. For instance, members of the research team from education attended the meeting about engineering design led by the faculty from engineering. The reverse was true, too, with engineering faculty learning about assessment from the education faculty. Integration of the faculty into the collaboration as both leaders and learners highlights a benefit of pursuing collaboration across disciplines.

The preservice teachers' role during this first term was to learn the scoring rubric and score student responses. Additionally, they observed several class periods of the engineering course to get a better understanding of the engineering students' experience and the pedagogical approaches used in the class. At the end of the term, the preservice teachers provided written feedback covering many areas including how they would change the assessment strategy, the engineering course, and how they thought their experiences with engineering had changed their attitudes toward teaching math, science, and problem solving. The students stated that now they have a deeper understanding of what they have learned in the education courses because they had a chance to put their knowledge into practice, and the practice helped them better understand their role as teachers. The timing of this hands-on practice was reported to be very well related to the knowledge they get through the two Ed P 310 and 357. In their written feedback, students mentioned that they as future teachers feel more comfortable teaching science and math related topics and using technology in their teaching. Additionally, the students understand analytic rubrics and feel more comfortable using them in their classroom after their involvement with the engineering course.

RESULTS FROM THE FIRST TERM

The following was learned during the first term of implementing the collaboration between education and engineering:

- Rubric development is iterative. Training the preservice teachers in using the rubric led to many clarifications and improvements to the rubric.
- While one original goal was to have the preservice teachers score the nearly 300 student responses, only about 50 were scored. It was learned early in the project that to get the preservice teachers truly involved, we had to ensure that they were learning useful skills in this project. Learning how to construct an analytic rubric and how to teach it to others are valuable skills for the preservice teachers. Scoring several hundred responses was more "grunt" work than it was beneficial to their learning.
- Tapping into the honors system (honors students can enroll in special sections of classes and are typically required to do an extra project) proved effective for the first term in that the number of preservice teachers was manageable and they were high quality students.
- With 15 weeks in a term and one hour per week with the preservice teachers, it was difficult to move beyond teaching the rubric to having them make changes to the rubric and construct a new strategy for assessing other objectives such as communication. Connecting participation in this study with a required course that the preservice teachers take is crucial so that they get credit for their work.
- The preservice teachers were able to learn content from the engineering course about engineering design sufficiently to become proficient scorers. One does not have to be an expert in the engineering design to be effective at applying the rubric.

NEXT STEPS

The first term has been dominated by efforts to establish the structure of the collaboration between the two colleges. With the structure established, efforts to move forward with improvements can begin. First, more preservice teachers (up to 25) will be involved in the assessment of the engineering course in spring 2004. We will be able to determine if our approach used with six students is scalable to 25. As a result of our collaboration and the feedback received from our preservice teachers, it was decided to give the opportunity for preservice teachers to register in spring 2004 for a three-unit course (ED P 358). This course would be an extension of the existing two-unit assessment course (ED P 357); students will take the exact same assessment course, but as an addition (for the one extra unit), will also be involved in observing and using assessment in the engineering course (ENGR 102). The students registered for this class will be taught topics related to classroom observation and assessment, will have hands-on experience in observing the ENGR 102 course, and will use the analytic rubric in the assessment of engineering students. At the end of spring 2004, the students will have the opportunity to give feedback about their course work.

Although it was hoped to expand the assessment beyond the single learning objective focused on engineering design knowledge, the amount of time between fall and spring terms is not sufficient for such expansion. The summer will be the time to expand assessment to other learning objectives such as communication skills. The input from the preservice teachers concerning how to effectively assess students' communication skills will be crucial in effectively expanding to a second learning objective. Similarly, major changes to the engineering course will not occur until fall 2004. At that time, there will be sufficient data from the previous academic year to

adequately assess if the changes made to ENGR 102 have any effect on students' design knowledge.

CLOSURE

Collaborations between engineering and education are a natural fit with potential benefits to both colleges. In the collaboration presented here, preservice teachers are exposed to more technical topics while applying assessment skills they study in their classes. Engineering students will benefit from improved classes due to the information learned from the assessment. While data analysis is not finished yet, the structure of the collaboration has been developed and implemented.

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BIOGRAPHIES

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