The Design and Assessment of an Engineering Problem Solving Course

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Abstract

The College of Engineering (COE) at the University of Texas at Arlington, a large urban public university, admits 700 – 900 new students to the college each semester. These enter the college with vastly different past experiences. Some students are entering directly out of high school while others enter the college with as many as 100 transfer credit hours. Past analysis by the college determined that many of this wide variety of students share common struggles in their first semester in a university setting. They have not yet developed the professionalism needed to be a successful at the university level, many students are not academically prepared, and many are lacking the communication skills necessary to successfully navigate an engineering curriculum. In order to address these issues and increase retention in the beginning years, the college undertook the design and development of a new course for first semester COE students. This paper will examine the process of designing the course, the lessons learned in the development and first semester implementation, the assessment plan as well as a look at the early assessment results, and the plans for the continuous improvement of the course.

Introduction

As in most baccalaureate engineering degree programs, the faculty in the College of Engineering (COE) at UT Arlington strive to give entering students the best possible start to their engineering studies. With a change in the university core requirements in Fall 2015 came the opportunity to rethink what type of start would most help our students be successful in their programs. With a charge from the dean to focus on student success and retention in engineering, a group convened for the year-long process of responding to this charge. Logically, this process began with a review of the current courses and a fresh setting of goals for the first engineering course in the degree plans for the college's majors. The result was a new course in engineering problem solving. The paper describes the process of design and assessment of that course, including the goals established, the design and development process for a new course, the lessons learned in that process, some preliminary assessments of the first semester of the course and the continuous improvement plan for the course going forward to future semesters.

Existing Introduction to Engineering

From 2004-2015, UT Arlington taught a one credit hour Introduction to Engineering course required for all incoming undergraduate engineering students. It was team taught by faculty from each of UT Arlington's engineering departments. The style of the class was traditional lecture (around 240 students in an auditorium setting) together with hands-on team activities, usually performed in the adjoining atrium.

Analysis by the College of Engineering (from course evaluations, performance in subsequent courses, etc.) indicated that incoming engineering students were getting good information and team-building opportunities, but were still experiencing common struggles that were not fully addressed by this course. These were roughly divided into three categories, though the issues are interrelated. First, the students lacked sophistication in applying existing math skills to engineering problems. Second, the students lacked communication skills, particularly technical writing skills as well as the appreciation for the importance of these skills. And finally, many simply lacked both professionalism and team skills required to be successful in engineering. It was determined that addressing each of these issues was crucial to a fourth overarching goal, that of increasing retention and serving our very diverse student population.

Goals and Design for New Course

A five member committee, composed of one member from 4 of the 6 engineering departments and the Academic Associate Dean of Engineering, was given the charge to develop a course for entering engineering students that more adequately addressed incoming student issues and increased retention. The committee started work in the fall 2014 semester with the ambitious goal of offering the new course in the fall 2015 semester. One of the first decisions made by the committee was that the focus would not be on reworking the existing Introduction to Engineering course but on developing a new course. In fact, the committee eventually settled on a 3 credit hour (2 lecture hours plus 2 lab hours) course format – allowing for four contact hours a week. The new course is named ENGR 1300.

Student learning outcomes were established thru discussion with stakeholders including other faculty, administration, and students. As mentioned earlier, they relate to the three issues of (1) technical preparation, (2) communication, and (3) professionalism.

Technical preparation and application

UT Arlington's incoming freshmen engineering students are typically either pre-calculus or calculus ready, although some do begin with college algebra. Transfer students run the gamut from beginning with college algebra to having completed calculus three. Regardless of starting level, students in later classes (for example, statics, discrete structures) were very often found to have difficulty with the practical application of math concepts, including unit conversion and algebraic manipulations in service to engineering problems. A major goal of the new course was to improve student performance in these areas. For that reason we thoroughly investigated using the Wright State model. (Klingbeil, 2014) We ultimately decided against this model for practical reasons. First, the Wright state model relied upon hands-on labs and lab facilities to bring about an appreciation for the importance of studying math. For the number of students we service (1400/year), the expense would be unsustainable. The second reason is that we wanted a single course to service all majors. We felt that expanding the Wright State (lab) model to include CSE, IE and BE, as well as EE, CE and ME, was not feasible. As part of the technical preparation, we also wanted to include introduction to logic and algorithms associated with programming.

Communication skills

Experience in the Introduction to Engineering course taught the committee that students often came to UT Arlington with weak technical writing abilities, even transfer students who had already had two semesters

of traditional English composition. Furthermore, those students tended not to appreciate the importance of communication skills to engineers. Thus, to emphasize the importance of communication to our incoming engineering students, we wanted to include it in the new course. We were emboldened by the success that other schools have had in this regard (Bundy, 2010). To ensure that communication skills would not be given short shrift, the English department was enlisted to help design and implement this portion of the new course. Key English assignments were to be introduced by English faculty and graded by trained English GTAs. The hope was not only to have quality English content be integral to the course but to also signal to the students the importance of communication to an engineering career. Clearly, assessment of this goal will come later as we see if there is a change in student performance in later classes, but at this point we do know that students are aware of our commitment to make instruction in written communication an integral part of their engineering learning experience.

Student professionalism and team skills

Many students lack knowledge of what it takes to be successful in school and in an engineering career. We decided that we did not want this course to be a study skills course; rather we wanted students to experience what it means to act professionally and learn to take responsibility for their education. For this reason, we wanted to rely upon team activities and an active learning approach. In order to do this, there needed to be appropriately designed classroom space that did not currently exist in the College of Engineering. Classrooms needed to be large, to accommodate a substantial number of students in each section, but at the same time designed in such a way that would promote an active learning environment and facilitate group work and discussion.

Course Design

A major part of the course design process was the investigating of existing course material / descriptions from other universities and current textbooks. The committee decided on "Thinking Like an Engineer, an Active Learning Approach". An important feature of the text was the emphasis on applying math concepts through active learning. Another was its coverage of MATLAB, a tool the committee deemed important to all engineering students. The material covered in the text would allow for the discussion of the algorithmic process and the engineering life cycle, and would provide students with tools and skills they would likely use in future courses and in their careers. In addition, we felt the problem solving approach would help students learn to be methodical and professional in their homework preparation. They will also be able to present their problem formulation and solution in a clear, concise, and professional format. The committee decided that the math co-requisite for the course would be pre-calculus or higher, realizing that this would create a teaching challenge because the students in the class would have a wide range of math backgrounds.

An additional consideration was that in order to increase the course credit hours from one hour to three, there needed to be a reduction in hours elsewhere in the degree plans. Since none of the engineering departments were willing to remove a technical course from their degree plans, it was decided to remove the second core English course, Rhetoric and Composition II. The justification for this change was that technical writing would be an integral part of the new course.

Results/Discussion

Practical Issues and Lessons Learned

The committee spent about eleven months in the design of ENGR 1300. The tasks included deciding on the content and format of the course, getting approval for and making all required catalog changes, designing the classroom space, and hiring faculty to teach the course. This section describes some of the issues encountered and lessons learned by the committee during the design and development of the course.

Instruction and Classroom Cost

The cost of implementing the course was heavily influenced by our determination to incorporate active learning. Active learning drove the requirements for class size, the classroom itself, and the instructional staff. The committee felt that each section should be limited to 70 to 90 students to foster connection with the instructor. To serve the expected enrollment, an ongoing cost to the college will include at least three full time instructors with the support of 15 undergraduate TAs. For the first year, the undergraduate TAs are paid from the AURAS project supported by NSF STEP grant funds.

UT Arlington had no room large enough to accommodate a class of this size in active learning seating arrangements; thus, a new classroom was designed specifically for this course. After talking with colleagues using active learning facilities around the country, it was decided to model the space on the "scale-up" facilities, and incorporate nine-person tables, white boards, and appropriate classroom computer technology. The space was carved from general use space, so no existing classroom space was lost. UT Arlington Facilities covered some of this cost, but the college also contributed to the facility renovation. The cost associated with the startup of the course has been significant, and should not be downplayed.

Implementation of a laptop policy for COE students was part of the technology decision-making that had to be done. One option considered was to furnish the room with desktop computers, but the trend for students to prefer their own computers rather than university computers has led to the widespread elimination of computer labs across campus. The decision to require students to provide their own laptops was based on the availability of student-version software and the ongoing benefit to the student of having a laptop for home and classroom use. To ease the cost considerations for the student, the committee opted for a two-pronged approach. Recommended laptop specifications for those purchasing new were published, with specs anticipated to last throughout their college years. Students who already owned a laptop were allowed to use those provided they met the UT Arlington minimum connectivity and software standards and operated software required for the course.

From the earliest discussions, even before the course format was set, the UT Arlington English department was willing to work with us and be incorporated into ENGR 1300. A set of relatively short written assignments, some suitable for group work, were designed by the English faculty with input from Engineering faculty. The English department assigned a core faculty member to coordinate and teach one section, with the remaining sections taught by English graduate students who would otherwise be teaching freshman English courses. The number and length of assignments was designed with the intent of making a nearly even swap with respect to cost/time utilization.

Incomplete buy-in and community college transfer issue

The committee undertook the task with the intent to serve the entire COE population, but the decision to work with a representative from four departments rather than one from each department proved to be a problem for implementation. Of the two departments that were not directly represented, one (EE) elected not to adopt the new course. Part of the problem in getting complete buy-in was the short timeline. The compressed timeline from start-up to course offering meant that final financial approvals for instructors and facilities were made very late in the catalog year. Departments not directly represented on the developing committee had little time to fully assess and adjust to the proposed course.

Because the course was designed to be fundamentally different from the previous Introduction to Engineering course, the way that transferred courses could be used as a substitute for it needed to be revisited. The Texas Academic Course Guide Manual requirements for Introduction to Engineering (ENGR 1201), the course taught by Texas community colleges, while similar to those of the previous Introduction to Engineering course at UT Arlington, are not at all similar to those of the newly designed course, ENGR 1300. For this reason, the committee recommended that all incoming students be required to take ENGR 1300. Local administration, however, preferred a transition period, where students who have taken ENGR 1201 at a community college be allowed to substitute it (combined with an English course) for ENGR 1300. While this satisfies the goal of matching transfer student expectations about their transfer credits, it creates a problem for the planned curriculum adjustments to accommodate the information taught in ENGR 1300. For example, because ENGR 1300 includes basic operational capability in MATLAB, instructors of later problem-solving courses such as engineering mechanics and numerical analysis planned to begin using the tool in their classes. With some of the population allowed to substitute a course with different content, it will take some additional work to directly take advantage of the ENGR 1300 content in those later courses.

Assessment Plans and Early Results

Considering that the primary focus of ENGR 1300 was to increase student retention, and ultimately graduation, in engineering, it is obvious that statistical comparisons of student retention of those who have attempted and passed the course to those who have not taken it will play a critical role in assessment. This comparison will be performed at numerous points in the curriculum to learn where ENGR 1300 is having an impact on student performance and retention, primarily by comparing grades in mathematics, science and engineering courses. However, it is important to note that one of the goals of the course is also to help students recognize at an early point in their curriculum that engineering may not be for them. As discussed earlier, students taking this course begin their engineering studies at varying points in their college experience and with significantly different academic preparation, which presents some challenges to assessing the course's impact on retention in a global way.

Other goals of the course, such as increased proficiency in basic mathematic skills, improved communication skills, and increased professionalism, will also be assessed primarily through surveys of student, TA and faculty opinions. These surveys will also be used to make improvements in the course.

We will also attempt to identify factors in student preparation that have led to their grade in ENGR 1300. Initially it is planned to look at the academic preparation factors and demographics but future assessments might include human factors such as attitude, expectations and resiliency.

Assessment Strategies

The initial plan in the statistical comparison of retention using course pass rates is to compare those students who passed the course to those who did not take it, in as many ways as is possible. The control group, those who have not taken ENGR 1300, contains several small populations. It includes Fall '15 entering electrical engineering majors, transfer students who had completed an Introduction to Engineering course as well as the second semester of freshman English, and students who did not take ENGR 1300 in their first semester but will take it in their second semester. The comparison will be made in the pass rates in mathematics, science, and engineering courses whenever possible. A comparison to prior years' rates in these same courses will also be included.

Surveys of students, TAs and faculty in ENGR 1300 and in other courses will be used to assess the effectiveness of the course in retention. Examples of the survey questions for the students are:

- Did the engineering problem solving class help you in the math course you were taking in the same semester?
- If not, did it help you in any other course taken in the same semester?

We believe that the course instructors and TAs will provide very valuable feedback on the effectiveness of the course and plan to also survey faculty in key subsequent courses to see if they notice any improvement in some basic preparation and skills over previous semesters.

Early Results

The primary analysis will involve comparing those who passed the class with those who dropped or failed. Special interest will be in looking at these two groups with regard to variables such as: math preparation, high school / community college preparation, and demographics. Results of this analysis are expected by the time of the conference presentation. However, with regard to two of these factors, other considerations will also be recognized.

The level of mathematics preparation required for this class is qualification for pre-calculus, which at our institution means appropriate scores on a math placement test or completion of college algebra. This admits students to the class with a wide span of mathematics backgrounds. Analysis of mid-term grades by mathematics level was done and similarly final exam and final course grades as related to mathematics background will be analyzed.

Some additional opportunities / needs for assessment arose during the first semester the course was taught. For example, we are now interested in a difference in performance in ENGR 1300 between students who had a high school chemistry and/or high school physics course and those who did not have these courses. ENGR 1300 uses many problems that come from the domains of chemistry and physics in teaching problem solving. For example, dimensional analysis is a major component of the Chemistry for Engineers class taught in the Chemistry Department. It is clear to the instructors that working this kind of problem does not require a full understanding of chemical processes, but some students felt they were disadvantaged by not having a full understanding of the background for the problem. Thus many students who were struggling with the problem solving class felt that their difficulties stemmed from an inadequate high school science background. One tends to discount this feeling somewhat since students also complained that they could not handle a break-even problem because they had not studied "advanced

economics". However, we plan to investigate a linkage between success in this class and high school chemistry and/or physics.

Continuous Improvement Plan

Plans for continuous improvement for the course involve several data collection and analysis activities from which needed changes will be determined.

Short Term Plans

First, course feedback is solicited at the end of a course by the university-mandated Student Feedback Surveys (online) which provide typical feedback on the administration of the course and effectiveness of the instruction. Both quantitative and qualitative feedback is requested, with answers to standard questions being collected on a five point scale. Additionally, free-form comments are requested in answer to questions about what attributes of the course or the professor helped you learn the material and what attributes did not.

For ENGR 1300, about two weeks prior to the end of the class, class time was allotted to the completion of an online survey developed by the instructional staff. Over 400 students provided responses to a set of six questions. That collected information is still being analyzed.

These feedback mechanisms provide a wealth of student opinion information which is useful in the tweaking of the organization of instruction for the subsequent offering of the course.

Longer Term Plans

It is planned in future ENGR 1300 classes to add first week and final week testing of several skills such as basic mathematics and problems solving to provide more quantitative information for analysis. A similar assessment will be done with student communication skills.

The analysis of the data on pass rates / drop-failure rates as a function of a number of factors (math preparation, concurrent math class, math placement scores, high school science background, transfer status, SAT / ACT, etc.) will allow us to more effectively target the instruction of the class.

Conclusion

Increasing the amount of instruction, practice, and contact that undergraduate students entering the College of Engineering receive was an important step for the college toward increasing student success and retention. A significant step in the implementation of that plan was the increase in credit hours from the one-credit hour Introduction to Engineering to the three-credit hour Engineering Problem Solving course. This increase in credit and contact hours allowed for more instruction in problem-solving skills, technical communication skills, and professionalism and teamwork skills. Throughout the design and first semester implementation of the course many lessons were learned by the design team. Most of the problems encountered were able to be overcome, but others are still a work in process as the course continues to evolve and improve. Aiding in the direction of that evolution will be on-going assessments of the achievement of the learning outcomes and retention of engineering students. Initial assessments from the first semester of teaching the new course will be presented at the ASEE GSW conference. These

initial assessments, as well as more far-reaching, longer term assessments will likely lead to more lessons learned as improved retention goals continue to be a focus of the College of Engineering at UT Arlington.

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