Lessons Learned: Integrating Active Learning into Undergraduate Engineering Courses

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Dr. Browning was named Dean and David and Jennifer Spencer Distinguished Chair of the UTSA College of Engineering in August 2014. Previously she was a faculty member at the University of Kansas for 16 years, and served 2 years as Associate Dean of Administration. While at KU, Dr. Browning twice was awarded the Miller Award for Distinguished Professional Service (2004 and 2011) and was the 2012 recipient of the Henry E. Gould Award for Distinguished Service to Undergraduate Education. In 2015 she was name a Purdue Distinguished Woman Scholar. In 2016 INSIGHT into Diversity magazine presented her with an Inspiring Women in STEM award.

Dr. Browning's research interests include structural engineering, earthquake engineering, engineering materials, and reinforced concrete design and analysis. She has conducted research to improve the durability of concrete bridge decks through studies of corrosion protection systems and low-cracking high performance bridge decks. She also is active in research to improve the design and performance of concrete buildings and bridges subjected to earthquake motion. She received the American Concrete Institute's Young Member Award for Professional Achievement in 2008 and was named an ACI Fellow in 2009.

Browning is a Co-PI with 6 other institutions in an NSF IUSE grant to develop procedures to affect cultural transformations in engineering education. She also is Co-PI of the leadership team (Network Coordination Office) for the NSF Natural Hazards Engineering Research Infrastructure (NHERI).

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Introduction

Student success is an ongoing concern in undergraduate engineering courses where high attrition rates are common. Inadequate prior preparation, lack of engagement, and difficulty of the content [1, 2, 3, 4] are some of the factors that produce these outcomes. One main challenge in undergraduate engineering and STEM courses is the predominant, traditional mode of instruction, which is lecture-based with the instructor speaking most of the time [2]. In this scenario, students are passive learners who mostly sit and receive information. Discussions are rare, and involve simple questions and answers with the instructor still speaking the majority of the time. To combat high dropout-withdraw-failure (DWF) rates in their courses, the College of Engineering at the University of Texas at San Antonio (UTSA) joined a multi-institutional grant project (TRESTLE) aimed at improving student success in STEM through course redesigns and transforming teaching practices to include more active learning approaches to improve undergraduate engineering education [5]. These course transformation projects use an embedded experts model [6, 7] in which engineering faculty were paired with education experts to transform course design and teaching practices to include more active learning approaches. Embedded experts are education experts who work with STEM content area faculty to transform their courses; as such these education experts are "embedded" within the STEM college and departments. This poster paper presents the current results of engineering faculty's participation in this course transformation process and their teaching practices.

Course Transformations

The foundation of TRESTLE's work is based on the Science Education Initiative model, which promotes data-driven course redesigns: an iterative process in which faculty are engaged in ongoing evaluation of what their students are supposed to learn, what they are actually learning, what evidence-based pedagogical approaches will help their students get to their goals, and how these factors inform one another [6, 7]. To participate in the course transformation program, engineering faculty had to write a proposal for the courses they wanted to redesign, with endorsement from the department chair. Faculty who participated were expected to evaluate and disseminate the outcomes of their course transformations to other faculty in their department, especially when other faculty were to teach these redesigned courses. Active learning approaches such as student response systems, interactive digital materials, group-based assignments, project-based and problem-based learning, adaptive assessments, and peer-assisted learning were emphasized. The actual techniques incorporated into the class design depended on the course, the faculty's need assessment, and resources available. The purpose of integrating active learning approaches in the classroom was to engage students in meaningful and authentic learning experiences. Thus, this project prepared faculty members to integrate more learner-centered and active learning strategies to improve student achievement and success. Ultimately, these transformative approaches would lead to a change in these faculty's teaching practices. They would also impact future iterations of the course while also expanding to other instructors of the same course. All course transformation projects were completed in Fall 2018, and our final year of evaluation to examine the efficacy of the intervention is in progress. We worked with four departments on their course transformation projects. Each department selected a set of courses in which the same active learning approaches would be applied: 1) Civil and Environmental Engineering – authentic learning, clickers, interactive textbooks; 2) Electrical and Computer Engineering – adaptive assessments with follow-up exercises and videos, questioning techniques, adapting recitation courses; 3) Biomedical Engineering – peer mentoring/tutoring, project-based learning, questioning techniques; and 4) Chemical Engineering – problem-based activities, collaborative/group activities, flipped classrooms. All projects also included a revision of the syllabus, course objectives, and course alignment.

Observations and Interviews

Observations were conducted by the embedded experts in ten courses and over 90 individual observations to identify the extent of active learning integrated into these courses before and after the transformation project (over the span of five years). The Classroom Observation Protocol for Undergraduate STEM (COPUS) [8] was used to note the frequency, but not necessarily the extent, of particular behaviors of students and instructors that demonstrate these active learning strategies in each class. Most COPUS observations were conducted by one embedded expert, but approximately one-third of observations had two embedded experts for inter-rater reliability. We also conducted end of the semester interviews with instructors of the courses each semester at and after transformation time. The interviews examined how transformation efforts affected course content, pedagogy, materials, and strategies. Questions also explored the helpfulness of embedded experts and instructor involvement in educational research. Based on our COPUS observations, student data collected, and interviews, we were able to draw some lessons learned from our course transformation efforts may benefit other engineering programs interested in course redesigns and adopting the embedded experts model, as discussed below.

Lessons Learned

We continue to monitor the extent to which these transformations impact a department's culture as a whole around teaching and teaching strategies. Recent findings showed that these course transformation projects did help in improving student achievement and faculty active teaching practices [9]. We have also found that it has helped faculty, particularly new faculty members, develop their teaching as they transition from graduate school or industry jobs to academia. Students also found that the active learning approaches that the instructors integrated in these redesigned courses were useful to their learning [9, 10]. Our team can share lessons learned from our embedded experts model in undergraduate engineering education:

- Collaboration between the embedded experts and engineering faculty was generally successful. The engineering faculty found the embedded experts' collective expertise in pedagogy, instructional design, and assessment useful. The engineering content was not a barrier for this collaboration; that is, the embedded experts (faculty and graduate students from education) were successful in guiding the engineering faculty's course transformations without a deep understanding of the content. Even though the embedded experts' support was subsiding due to the close of the project, there were still some faculty who occasionally reached out to the embedded experts for support as well as future funding opportunities. Thus, we see that there are many opportunities for education faculty to work with other content area faculty to help improve teaching, without the potential hindrance of disciplinary knowledge.

- More systematic, sustained support from embedded experts may have helped engineering faculty to not only increase but also sustain active learning opportunities within transformed courses. Further, more encouragement to share materials and strategies from these transformed courses with other faculty would have bolstered the positive results of the project, as transformations did not necessarily carry over to the next instructor or other instructors in the same semester. Having the department chair's support for these transformations was a requisite for funding and working with the embedded experts, and allowed for the transformed courses to continue on without the initial instructor. However, this did not happen as frequently as expected, specifically for our EE courses, which had the largest variance in instructors. In talking to some of the newer instructors, they were not aware of any of the changes, but were interested in hearing more about these approaches. Upon reflection, the participating instructor, the department chair, and the embedded experts could work together prior to each semester to review the new course designs with the upcoming instructors.
- The embedded experts team continued observations and interviews each semester to investigate the fidelity of the transformations. The most successful cases we saw in terms of sustaining course transformations were the engineering faculty who were most engaged in the embedded experts team. However, this success was due to the fact that we were working with the faculty who started the initial transformation project and taught the same courses each semester.
- Though students generally had positive perceptions of the active learning approaches such as project-based learning, peer mentoring, and adaptive course designs, we found from the embedded experts' classroom observations that students also need some preparation to work effectively in these non-traditional classrooms. Our training with the faculty members involved getting them used to an active learning environment, and it may be useful for faculty to provide similar, brief training to students.

COPUS data showed that the course transformation projects supported faculty in moving away from traditional lecture-based systems of teaching. After the initial transformations, faculty did less direct teaching and the students did less passive learning. Follow-up data, however, showed that while participating faculty members continued to apply more active learning techniques in their classes, but other faculty members who taught the same course post-intervention did not. Our data and experiences to date show that there is great potential in this type of cross-campus, interdisciplinary collaboration.

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