2018 ASEE Annual Conference & Exposition
June 24–27, 2018 Salt Palace Convention Center Salt Lake City, UT

Paper ID #22475

Increasing Student Engagement in Engineering Through Transformative Practices

Dr. Vittorio Marone, University of Texas, San Antonio

Vittorio Marone is an Assistant Professor of Instructional Technology in the Department of Interdisciplinary Learning and Teaching at The University of Texas at San Antonio. He earned his doctorate in Education in a dual-degree program between the University of Padua and The University of Tennessee. He also holds a doctorate in Languages, Cultures, and Societies from Ca' Foscari University of Venice. His research interests include new literacies, youth cultures, games and learning, music technology, and multimodality. He presented his work at national and international conferences such as GLS (Games + Learning + Society) and G4C (Games for Change). He is the author of the book La Quotidianità dell'Assurdo (The Everyday Absurd, Archetipolibri, Bologna, 2010).

Mrs. Robin L. Nelson, University of Texas, San Antonio

Robin Nelson is a doctoral student in the Department of Interdisciplinary Learning and Teaching and is pursuing a cognate in Instructional Technology at the University of Texas at San Antonio. Her research interests include the development of TPACK in preservice teachers and evidence-based teaching strategies. She is a Graduate Research Assistant for the TRESTLE project at UTSA.

Ms. Stephanie Ann Garcia, University of Texas at San Antonio

Stephanie Garcia is a Graduate Research Assistant with a MAED from the University of Texas at San Antonio with a concentration in Curriculum and Instruction. Her work with TRESTLE involves training Peer Assisted Learners (PALs) and supporting engineering faculty in implementing culturally relevant pedagogy and other course transformation projects.

Dr. Emily Peterek Bonner, University of Texas, San Antonio

Emily Bonner is an Associate Professor of Curriculum and Instruction specializing in mathematics education. Her research interests focus on professional development and equity in schools.

Dr. Timothy Yuen, University of Texas, San Antonio

Timothy T. Yuen is an Associate Professor of Instructional Technology in the College of Education and Human Development at the University of Texas at San Antonio. His research investigates how learning technologies and transformative practices can improve learning, engage students, and broaden participation in computer science and engineering.

Dr. JoAnn Browning P.E., University of Texas, San Antonio

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).

Increasing Student Engagement in Engineering Through Transformative Practices

Introduction

Undergraduate engineering courses often have high dropout, withdrawal, and failure (DWF) rates, which prevents students from completing their degrees in a timely manner or persisting in the engineering major [1, 2]. At the University of Texas at San Antonio (UTSA), the College of Engineering (COE) has been engaged in an ongoing endeavor of improving student success in its undergraduate programs. Many of the challenges observed by our faculty are similar to those recently faced in other undergraduate engineering programs, such as inadequate student preparation in mathematics and science [3], focus on teacher-centered instruction [4], and lack of student engagement [2]. In response to these calls for improving student success, the COE has implemented a program that promotes undergraduate course transformations through an embedded expert model. The program pairs faculty and doctoral students from the College of Education and Human Development (COEHD) with faculty in the COE to transform course designs and teaching practices to increase student engagement and success. This paper examines the impact of three specific course transformations within the program in terms of student and instructor outcomes.

Course transformation program

The goal of the course transformation program is to improve student learning by innovating course designs and teacher practices. This program is based on the Carl Wieman Science Education Initiative (CWSEI), which provides a framework for transforming courses by using research-based educational strategies and data-driven instruction to improve student learning. Though CWSEI is discussed within the context of the sciences, it has been adapted to address all of STEM (Science, Technology, Engineering, and Mathematics) fields. For the COE, it has been adapted to focus entirely on engineering.

The CWSEI asks instructors to investigate what students are actually learning in order to find ways to improve their learning experiences [5-7]. Research-based approaches inform the design and the pedagogical strategies to be implemented in the course transformations. Observational data from target courses and participating instructors are also used. Thus, according to this framework, course transformations require iterative refinement (after the implementation, the revision process starts again). Further, details related to each cycle of transformation depend greatly on the situated needs of individual courses, students, and faculty.

Embedded expertise is a core aspect of this framework and the transformation process [7, 8]. Education experts are embedded into STEM departments and work closely with faculty in redesigning their courses. At UTSA, embedded experts (the first five authors of this paper) are full-time faculty and doctoral students in the COEHD whose experience and expertise include STEM pedagogy, instructional design and technology, and teacher education [7]. A continuing theme that runs through the course transformations is that of engaging students with appropriate and meaningful learning experiences.

Student engagement in engineering education

A multitude of factors can influence student engagement and retention in engineering programs, such as students' background and preparation, attitudes, behaviors, self-efficacy, motivation, and learning strategies [2, 9]. As such, universities across the world are implementing initiatives that seek to transform engineering education in order to increase student engagement and reduce dropout rates from courses and programs [10-12]. These initiatives demonstrate that student engagement is a multidimensional construct that needs to be approached through a holistic perspective that transcends the presentation of content in the classroom [13]. Instructors can appeal to students' personal interests, offer opportunities for self-reflection, or implement peer-supported, active, and research-based learning activities [14], as well as promote project-based teaching, student collaboration, and continuous feedback and assessment [15]. Studies also suggest that such initiatives should take place in contexts that are familiar to students and situated within the "real world" and the global challenges of society [16], which also reflects one of the reasons why students select an engineering major, namely their desire to help advance society [17].

Engineering students expect to be engaged by faculty [14], which is related to instructors' teaching philosophy as well as their ability to convey enthusiasm for the discipline and create opportunities for students to participate in active learning (e.g., labs, simulations, or discussions). This expectation brings attention to the need for the development of pedagogical competences among both engineering instructors and students in order to implement new learning and teaching strategies and provide relevant educational experiences to all learners [18]. Recommended learner-centered strategies in engineering education include problem-based learning, hands-on activities, peer instruction, collaboration between teachers, and a multilayered approach to assessment [18]. With most engineering doctoral programs focusing on preparing the next generation of researchers, there are few instances where future professors and instructors are being adequately trained in engineering pedagogy. Further, engineering faculty may not be aware of evidence-based educational research focused on teaching strategies in engineering [8]. Therefore, there is a need to prepare engineering faculty to embrace active and learner-centered approaches that make engineering relevant to students' interests and lives, which can significantly increase their success in STEM fields [19].

Transforming undergraduate engineering education at UTSA

Increasing student engagement and retention in engineering courses through innovative pedagogies is a complex task which should not exclusively focus on single courses, but rather extend to the whole teaching community [15]. While the focus of the project at our university is on individual courses and groups of faculty members, its broader goal is to build a community actively engaged in improving undergraduate teaching practices. The first step in this direction is the collaboration between engineering faculty and educational experts to transform engineering courses to improve student engagement and success. Through our course transformation program, competitive awards were made to the engineering departments, which provided necessary resources for course transformations. Proposals submitted by engineering faculty outlined the challenges they and their students faced in the targeted courses, such as low pass rates or lack of student engagement, and possible improvement ideas.

Selected engineering faculty met with the embedded experts to discusses activities, specific needs of the course, targeted areas that could be addressed, and potential strategies for improving student learning. Embedded experts helped refine these ideas and provided additional approaches to address instructors' and students' needs, which often involved learner-centered strategies to engage students. Embedded experts also conducted observations of the courses and the participating faculty to make more specific recommendations and provide additional support, such as strategies to implement pedagogical approaches or technological resources. Thus, a valuable partnership between engineering faculty and embedded experts developed throughout this project as both parties are committed to improving engineering education.

Current course transformations

In the last competitive cycle (2016-2017), course transformation projects were accepted from the Electrical and Computer Engineering (EE) and Biomedical Engineering (BME) departments with the goal of transforming their courses. Each department focused on one or more "gateway courses" (to either the major or the next level of courses) in their respective programs. The target semester for when these transformed courses would be taught was Fall 2017.

Starting in Spring 2017, embedded experts worked with engineering faculty in order to better understand the needs of each course and discuss ways in which they could improve teaching and learning. In Spring 2017, embedded experts conducted classroom observations using the COPUS protocol [6] to collect data on teaching practices in the classroom, course content and activities, classroom environment, and student engagement. Data were collected prior to the transformation process and were used to recommend teaching strategies and redesign the courses. During Summer 2017, the embedded experts facilitated the development and implementation of teaching strategies and integrated other research-based approaches to address the issues reported by engineering faculty and what was observed in the classroom. The engineering faculty and their teaching assistants received training from the embedded experts, as well as other university services, in order to effectively implement the course transformations. The following sections will discuss in detail the course transformations within each program, data collections, and analyses.

Electrical and Computer Engineering (EE)

The Department of Electrical and Computer Engineering (EE) proposed transforming four courses. At the time of this paper, two courses were transformed and taught by Fall 2017. The other two courses are still in progress with respect to being transformed or taught. The four courses were marked by the EE faculty as being gateway courses to the next level of the undergraduate degree program. The EE faculty reported high dropout, withdraw, and failure rates in these courses, due to the difficult nature of the covered concepts and the need for students to have more practice and problem-solving opportunities. They also reported the need for students to have more individualized resources and instruction to help them review the topics. The major transformation strategy for these courses was implementing adaptive assessments in order to allow students to access additional resources, based on their learning needs, as evidenced by their performance in the assessment. Also, for further support, recitation sections would cover topics that students had missed in the assessment. Only the two courses that were transformed and taught are presented in this paper. The courses were Network Theory (EE1) and Analysis & Design of Control Systems (EE2).

Biomedical Engineering (BME)/Academic Inquiry and Scholarship (AIS)

The Department of Biomedical Engineering (BME) proposed transforming their introductory course. The main issue of that course was that it had co-requisite requirements. The knowledge students needed for this course was provided in courses they had to take concurrently. This challenge was due to course sequencing designed to allow students to complete the program in four years. The major transformation strategies for this course were to implement peer-assisted (PAL) and project-based learning (PBL). This system featured peer-assisted learning assistants (PALs) to provide students with support to navigate concepts from their co-requisite courses in a project-based setting. The course also included a peer mentor who acted as a coach and advisor for students. Whereas the previous iterations of this course had some PBL components, the transformed course was fully based on the PBL approached and partially included "flipped classroom" activities. Also, this transformation resulted in the creation of a new course called Academic Inquiry and Scholarship (AIS) for students in Technology, Engineering, and Mathematics majors.

EE and BME/AIS

For both EE and BME/AIS transformation projects, embedded experts integrated learner-centered approaches such as project-based learning to create more engaging and authentic learning experiences [20], culturally relevant pedagogical practices to address the needs of culturally and linguistically diverse student populations [21], and questioning techniques to promote higher-order thinking. All these strategies were implemented to engage students in the learning process by making them active participants, providing more individualized instructional support, and presenting the topics in meaningful real-world contexts. The embedded experts created workshops for engineering faculty members, their teaching assistants, and peer mentors (in BME/AIS).

Methods

This paper focuses on the results of the three course transformations in terms of student and instructor outcomes. The questions driving this investigation are:

- How were the course transformations implemented?
- What were the impacts of the course transformations on student outcomes in terms of achievement and perceptions of the transformation strategies?
- What were the impacts of the course transformations on teacher outcomes in terms of their teaching practices and beliefs?

Pre- and post-transformation student and instructor data were used to compare how these strategies impacted student outcomes and teacher practices. An analysis and comparison between pre- and post- data was used to identify changes in outcomes and practices.

Data

A variety of data sources were used to gather feedback on the course transformations. Pre-transformed course data were collected during the Spring 2017 semester while transformed course data were collected in the Fall 2017 semester. Specifically, the following data were collected for this study:

- COPUS – The Classroom Observation Protocol for Undergraduate STEM (COPUS) instrument [6] was used to collect observation data on how instructors and students interacted and participated in the classroom. The COPUS instrument records the frequency of actions performed by students and instructors, such as asking and answering questions, using clickers, or performing group work. COPUS data were collected for the target courses before and after the course transformations.
- Student Grades – Students' final grades were collected from the instructor of the target courses in the semester before and after the transformations. The engineering faculty in this study taught both the pre- and post- transformation courses.
- Student Survey – A survey was administered in the middle of the semester (for the transformed courses) asking students to report their perceptions of main transformation strategies and how they impacted their learning, as well as any recommendations they had for improving them.
- Interviews – The research team conducted semi-structured interviews with the engineering faculty after the transformed course semester had ended.

Results

For EE1 and BME/AIS, the pre (Spring 2017) and post (Fall 2017) transformation courses were taught by the same instructor. EE2 courses were taught by a different instructor in the before and after transformation semesters; however, both instructors were part of the transformation project. The faculty member who led this course transformation process with the embedded experts taught the transformed course in Fall 2017.

COPUS results

The COPUS is an instrument that tracks what categories of actions the teacher and students are performing. In some cases, several actions can occur during the same time interval (measured every 2 minutes). Student actions include: student talking to class (answering and asking questions, whole class discussion, and student presentations), student receiving information (listening to the instructor), and students working (individual thinking/problem solving, clicker questions, working in groups with worksheet activity, and other group activities). Instructor actions include instructor presenting (lecture, real-time writing, and demonstrations/videos) and instructor guiding (follow-up, posing and answering questions, clicker questions, and one-to-one student interaction).

Observations were collected three times midway through the semester—all observations were collected within three weeks for each course. Data highlight the most frequently observed categories of action and present an average frequency across the observations. The individual actions have been collapsed into the most frequently observed categories across the three courses. Collected data represent the average percentage of recorded actions compared to the total number of actions recorded. Table 1 shows the outcomes of the collapsed COPUS observations for each course.

Table 1. Collapsed COPUS observation results for pre- and post- transformations.

	PRE-TRANSFORMATION	POST-TRANSFORMATION
EE1	Student Talking to Class: 20% Student Receiving Information: 77% Students Working: 0% Instructor Presenting Information: 88% Instructor Guiding: 11%	Student Talking to Class: 33% Student Receiving Information: 55% Students Working: 0% Instructor Presenting Information: 68% Instructor Guiding: 26%
EE2	Student Talking to Class: 31% Student Receiving Information: 65% Students Working: 4% Instructor Presenting Information: 74% Instructor Guiding: 23%	Student Talking to Class: 34% Student Receiving Information: 53% Students Working: 6% Instructor Presenting to the Class: 61% Instructor Guiding: 32%
BME/AIS	Student Talking to Class: 63% Student Receiving Information: 34% Student Working: 0% Instructor Presenting to the Class: 37% Instructor Guiding: 38%	Student Talking to Class: 32% Student Receiving Information: 21% Students Working: 28% Instructor Presenting Information: 8% Instructor Guiding: 62%

Before the transformation. Before the course transformations were conducted, COPUS observation data indicated a need for a more active and student-centered approach to teaching [19], since all three courses relied more heavily on presentation style instruction. This resulted in students spending much of the class listening (receiving the information) passively. The instructors of the EE courses chose to focus on reducing their drop, failure, and withdrawal rates through the creation of an adaptive assessment system for each class topic. A list of topics was also generated to improve the facilitation of recitation sections together with a set of customized online resources.

The BME/AIS course focused on transforming a traditional presentation style course to a more active and student-centered learning experience through the expansion of project-based learning modules and the integration of a peer-assisted learning model [22]. COPUS data show that students were talking to the class (answering questions, asking questions, whole class discussions, and presenting) and working (individual thinking/problem solving, working in groups, or other group activities), however, activities were missing.

After the transformation. After the transformation of each course, COPUS results indicate a reduction in instructor presentation and an increase in student active participation. EE1 and EE2 courses reduced instructor presenting time by 13% and 20%, respectively. The EE2 course also increased instructor guiding from 23% to 32% and slightly increased working and talking to class. The EE1 course jumped from 11% to 26% in guiding and from 20% to 33% in talking to class. Data show the dramatic decrease in BME/AIS instructor presentation from 38% to 8%, and a dramatic increase in instructor guiding time from 38% to 62%. While student talking to class dropped by 31%, discussion continued to occur within small groups of students, instead of the entire class. This shift, accomplished by introducing PBL activities, resulted in a 30% increase in working (individual thinking/problem solving, working in groups, or other group activities), which further increased student active class participation.

Overall, the collapsed observational data related to student and instructor actions show an improvement in student engagement and student-centered teaching practices across all courses. Both EE1 and EE2 courses increased student engagement through guided learning and by reducing instructor presentation time. The combination of more active and student-centered activities and a decrease in passive student learning also led to an increase in student performance. The BME/AIS course transformation showed student-centered learning in the working, receiving, guiding, and presenting categories. The student receiving category also decreased as the instructors lectured less and engaged more in guiding students.

Student pass rates and average grades

Table 2 shows the pass rates and average grade (AG) of each course. A passing grade is a letter grade of C or higher. Though increasing the pass rate was the major objective of this project, the AGs were also used to provide insight into the extent of the success of each course. Course AGs were calculated on a traditional US grading scale: A=4pts, B=3pts, C=2pts, D=1pt, and F=0pts. Student achievement data for the transformed courses taught in Fall 2017 are shown in the TRANSFORMED columns (courses taught by participating instructors). Student achievement data were also collected for two years for each course. The OVERALL PRE-TRANSFORMED columns summarize the data of all students counted together in the preceding two years. The original BME course is offered only in Spring semesters while EE courses have two sections every semester. The INSTRUCTOR PRE-TRANSFORMED columns show data from the last time the participating instructor taught the same course, which was also factored into the OVERALL PRE-TRANSFORMED columns.

Table 2. Student pass rates and average grades (AGs) for each course.

	OVERALL PRE-TRANSFORMED		**INSTRUCTOR PRE-TRANSFORMED**		**TRANSFORMED**	
	Semesters, number of students and sections	*Pass rate and AG*	*Semester and number of students*	*Pass rate and AG*	*# of students*	*Pass rate and AG*
EE1	Fall 2015 - Spring 2017 N = 313, 7 sections	72.2% AG = 2.04	Spring 2017 N = 45	73.3% AG = 2.2	N=55	83.6% AG = 2.56
EE2	Fall 2015 - Spring 2017 N = 158 (4 sections)	89.9% AG = 2.88	Fall 2016 N = 34	82.3% AG = 2.32	N=19	89.5% AG = 2.84

BME/ AIS	Spring 2015 - Spring 2017 128 (2 sections)	94.5% AG = 3.08	Spring 2017 N = 65	95.4% AG = 3.09	N=50	94.0% AG = 3.38

These data show some evidence that the course transformations had a positive effect on student learning outcomes. The transformed EE1 course showed a higher pass rate than previous semesters (over 10% increase) as well as a half point increase in the AG. The EE1 course saw a similar increase, as compared to the last time the same instructor taught the course. The EE2 course saw a minor decrease in pass rate and AG; however, the course saw an increase of 7% in the pass rate and half point increase in the AG. Similarly, the transformed BME/AIS course also had a slightly lower pass rate, as compared to the previous two semesters, as well as the last time the instructor taught the course. However, there was a .3 increase in the AG of the transformed course. Overall, the results show instances of progress across each of the three course transformation projects. The higher levels of increase of the pass rates in the transformed courses, as compared to the pre-transformed courses, suggest some improvement in the course design. For all the instructors, there was an increase in pass rates and AGs from the last time they taught the course, which may suggest that the instructors have improved their own practice.

Student survey data

Survey responses were collected from EE and BME/AIS students to identify perceptions about the adaptive assessment and Peer-Assisted Learning (PAL) interventions (i.e., what students liked and disliked about the intervention, suggestions to improve it, and general comments about the course). The online surveys utilized Likert scale questions that were e-mailed to students, with a response rate of 89% for EE students and 70% for BME/AIS students, respectively.

Adaptive assessments. Sixty-one (N=61) EE students responded to the survey on adaptive assessments. Students found the adaptive assessments supported learning through additional practice and 70% of students found adaptive assessments to be somewhat to very useful (Fig. 1). A major concern reported by the faculty was that students did not have enough practice time, and the adaptive assessments provided additional resources based on how the students responded. One student explained: “The quiz asks challenging questions that provoke critical thinking. This makes future questions regarding similar topics to the quiz easier to solve.” Another student noted: “I like that it provides examples to the material covered in class and gives a general idea of how you’re doing and what you need to study more.” However, some students felt the adaptive assessment should provide immediate feedback and additional attempts for each problem: “It doesn’t say if we enter the wrong or the right answer, and we don’t get another chance.” An additional concern was the specificity the adaptive assessment required for answers. A student reported: “Sometimes correct answers are counted incorrect due to formatting.”

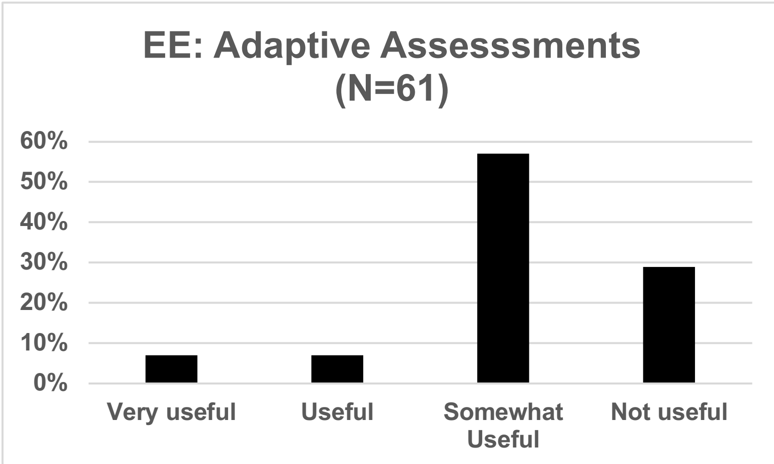

Figure 1. EE student survey: adaptive assessment.

Peer-assisted learning. Thirty-five (N=35) BME/AIS students responded to the survey on peer-assisted learning. Survey results indicate students found the PALs to be knowledgeable and approachable with 65% of BME/AIS students finding them useful or very useful in improving their learning (Fig. 2). One student explained: “They are always willing to answer any questions that we might have and give us ideas on how to solve problems. They sit down with us and really contribute to our discussion and planning.” Another student noted: “They are engineers like us, and so it helps when we don’t know the answer to something.”

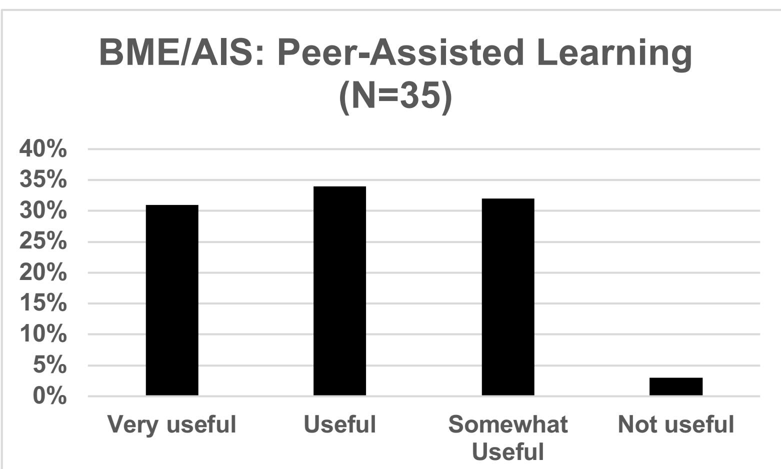

Figure 2. BME/AIS student survey: Peer-Assisted Learning.

Peer mentors. The majority of students (68%) found peer mentors to be convenient, knowledgeable, and useful for learning BME/AIS material (Fig. 3). According to one BME/AIS student, “The peer mentor meetings are very helpful for both the class and the future. It is always helpful to have someone experienced who has already gone through a majority of their engineering major.” Another student reported: “[The peer mentor] always works with us to make sure we succeed in our class. [He works] with our schedules to meet outside of class and does a lot of extra work to make sure we get the full experience out of this class.” The main concern expressed by BME/AIS students was that both PALs and peer mentors sometimes seemed uninformed. A student explained: “Sometimes we get several different answers to the same question because they weren’t told how to answer it.”

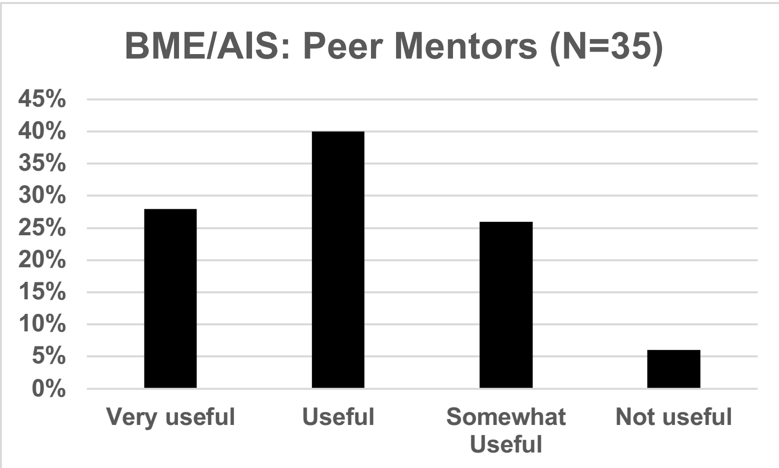

Figure 3. BME/AIS student survey: peer mentors.

Post-transformation instructor interviews

The researchers interviewed all three instructors of record of the courses asking them to reflect on the overall course transformation process in terms of outcomes related to student data and their experiences working with embedded experts.

Electrical and Computer Engineering. The EE faculty (for the EE1 “Network Theory” and EE2 “Analysis and Design of Control Systems” courses) noticed a large decrease in DFW rates after the course transformation, as well as an increase in grade averages. The faculty attributed the success to the changes made in recitation sessions, as well as the newly available online materials. The goal of their transformation was to create an adaptive assessment system for each class topic in an effort to improve grades and prevent withdraws. Through this transformation, not only were new adaptive assessments created, but the faculty also created new practice problems to engage students in critical thinking. These in-class and after-class activities, as well as rubrics and student feedback surveys, were all based on observed student difficulties and were created to improve the design of the courses and the recitation sessions. Student survey data served as a critical piece to help inform the faculty of any pedagogical and course changes that needed to be made.

The embedded experts worked closely with the EE faculty to create the adaptive assessments and develop online instructional materials for students. Furthermore, embedded experts supported the faculty in designing, developing, and implementing course transformations and facilitating professional development on topics such as critically relevant pedagogy and problem-based learning. With assistance from the embedded experts, engineering faculty stated that they learned to interact with their students more and made many other changes to their course content and design as a result of this transformation. The collaborative work with the embedded experts informed engineering faculty on what improvements needed to be made. The EE faculty have also shared their course transformations with their respective departments and will share their experiences in future conference presentations in efforts to disseminate evidence-based practices that are improving student learning and retention in their courses.

BME/AIS. The BME/AIS team focused on how to question and improve teaching styles to better engage students through activities, as well as provide similar instruction for PALs, peer mentors, and teaching assistants. There was substantial impact with the design and implementation of the PALs and peer mentor components. The curriculum, goals, and activities were completely re-designed. As such, the instructor also created new rubrics, quizzes, and project-based learning activities to increase and better assess student achievement. Moreover, hands-on lab activities, case studies, and other in and out of class assignments were designed. Student surveys and interviews were implemented by the instructor to improve student counseling, learning, and retention.

The embedded experts worked with the BME/AIS faculty in designing, developing, and implementing the PALs model into the BME/AIS course. Furthermore, they coordinated training activities for the PALs and peer mentors and developed and implemented PBL and culturally relevant training for the instructor, TA, and peer mentors. Overall, the project influenced teaching, guided curriculum development, and helped increase student engagement. The BME/AIS team informed the embedded experts that they have shared their course transformation with other colleagues within the COE and will be presenting it at conferences.

Summary

The course transformation program presented in this paper is a unique collaborative effort between the College of Engineering and the College of Education and Human Development at UTSA. The program strives to improve student success in undergraduate engineering programs by addressing common challenges that lead to drop-out, failure, or withdrawal. Challenges such as inadequate student preparation in mathematics and science [3], focus on teacher-centered instruction [4], and lack of student engagement [2] are some of the issues that have been addressed in the course transformations. The collaborative effort made use of the expertise of both departments. Engineering faculty brought their content expertise and previous course teaching experience, while the education faculty and doctoral students brought knowledge of educational strategies, such as project-based learning, culturally relevant pedagogy, peer-assisted learning, and adaptive assessment.

Data collected indicate an increase in pass rates and/or average grades in all three transformed courses, compared to the pre-transformed courses. While the BME/AIS course had a very minor lower pass rate, the overall student average grades increased slightly. The transformed course, according to the instructor, was more conceptually challenging and required a more active approach to learning, which may account for the slight drop in pass rates. The BME/AIS course also saw significant changes in the teaching/learning strategies based on the COPUS observations. There was a significant reduction in the amount of passive presentation of information and a significant increase in active student learning. Both EE courses also saw a drop in lecture presentation, but differed in the ways they engaged students in active learning.

The collaboration between engineering faculty and embedded expert from the College of Education and Human Development provided a unique opportunity to focus on solutions for a variety of student needs. Professional development provided support for engineering faculty to increase student engagement, reduce failure rates, and overall provide a more active learning environment. Data and interactions with the program team show that engineering instructors are making noticeable progress in applying educational strategies and culturally responsive approaches to teaching. Moreover, instructors are learning about students' backgrounds, which allows them to connect instructional content to students' lived experience [23, 24], reflect on their own practice, and make necessary adjustments. Overall, there has been a noticeable shift in many of these classrooms, with instructional decisions being based more often on student needs. In the BME course, for example, projects have been designed to align with students' interests and cultures through multiple forms of delivery. This use of cultural referents can engage and empower students in various ways, increasing their interest and agency in learning complex topics.

Conclusion

This paper presented the outcomes of three undergraduate course transformation projects across two engineering departments in which faculty reshaped their courses by implementing a learner-centered approach to teaching. In the collaboration between engineering departments and embedded experts in education, engineering faculty chose aspects of their courses they wanted to redesign, and education faculty and doctoral students worked closely with instructors to create evidence-based strategies to support the redesign efforts. Through weekly meetings, professional development sessions, classroom observations data, student surveys, and follow-up faculty interviews, the team collaboratively supported the transformation of the courses.

The results presented here show positive outcomes on student learning and faculty development. Students found the key transformation strategies (adaptive assessment and peer-assisted learning) to be useful to their learning experience. The engineering faculty appreciated the collaboration with education faculty and graduate students, advancing their practice to include more student-centered, active, and culturally responsive approaches to teaching. The results also provide useful formative feedback for future iterations of the transformations to implement evidence-based practices that can effectively reduce DWF rates by increasing student engagement. And for embedded experts, it has allowed them to further their research on effective engineering and STEM learning and teaching in higher education.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant No. #1525345. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. This work is done in collaboration with the University of Kansas, Indiana University, Queen's University at Kingston, University of British Columbia, University of California, Davis, University of Colorado Boulder, and the University of Texas at San Antonio.

References

[1] M. W. Ohland *et al.*, "Race, gender, and measures of success in engineering education," *Journal of Engineering Education,* vol. 100, no. 2, pp. 225-252, 2011.

[2] M. W. Ohland, S. D. Sheppard, G. Lichtenstein, O. Eris, D. Chachra, and R. A. Layton, "Persistence, engagement, and migration in engineering programs," *Journal of Engineering Education,* vol. 97, no. 3, pp. 259-278, 2008.

[3] G. Zhang, Y. K. Min, M. Ohland, and T. Anderson, "The role of academic performance in engineering attrition," presented at the 2006 ASEE Annual Conference & Exposition, Chicago, IL, 2006.

[4] M. J. Borrego, M. A. Padilla, Z. Guili, M. W. Ohland, and T. J. Anderson, "Graduation rates, grade-point average, and changes of major of female and minority students entering engineering," in *Frontiers in Education, 2005. FIE '05. Proceedings 35th Annual Conference*, 2005, pp. T3D-1.

[5] S. V. Chasteen, K. K. Perkins, P. D. Beale, S. J. Pollock, and C. E. Wieman, "A thoughtful approach to instruction: Course transformation for the rest of us," *Journal of College Science Teaching,* vol. 40, no. 4, p. 24, 2011.

[6] M. K. Smith, F. H. Jones, S. L. Gilbert, and C. E. Wieman, "The Classroom Observation Protocol for Undergraduate STEM (COPUS): A new instrument to characterize university STEM classroom practices," *CBE-Life Sciences Education,* vol. 12, no. 4, pp. 618-627, 2013.

[7] C. Wieman, K. Perkins, and S. Gilbert, "Transforming Science Education at Large Research Universities: A Case Study in Progress," *Change: The Magazine of Higher Learning,* vol. 42, no. 2, pp. 6-14, 2010.

[8] T. T. Yuen, E. Bonner, W. D. Cruz, R. Roby, J. Browning, and B. Merchant, "Embedded experts for undergraduate engineering faculty professional development," in *Teaching, Assessment, and Learning for Engineering (TALE), 2016 IEEE International Conference on*, 2016, pp. 389-391: IEEE.

[9] N. Honken and P. A. Ralston, "Freshman engineering retention: A holistic look," *Journal of STEM Education: Innovations and Research,* vol. 14, no. 2, p. 29, 2013.

[10] C. Crosthwaite and L. Kavanagh, "Supporting transition, engagement and retention in first year engineering," in *Proceedings of the International Conference on Innovation, Practice and Research in Engineering Education. Coventry, England*, 2012.

[11] R. M. Felder, G. N. Felder, and E. J. Dietz, "A longitudinal study of engineering student performance and retention. V. Comparisons with traditionally-taught students," *Journal of Engineering Education,* vol. 87, no. 4, pp. 469-480, 1998.

[12] M. W. Ohland and G. Zhang, "A study of the impact of minority engineering programs at the FAMU-FSU College of Engineering," *Journal of Engineering Education,* vol. 91, no. 4, pp. 435-440, 2002.

[13] A. D. Lambert, P. T. Terenzini, and L. R. Lattuca, "More than meets the eye: Curricular and programmatic effects on student learning," *Research in Higher Education,* vol. 48, no. 2, pp. 141-168, 2007.

[14] R. S. Heller, C. Beil, K. Dam, and B. Haerum, "Student and faculty perceptions of engagement in engineering," *Journal of Engineering Education,* vol. 99, no. 3, pp. 253-261, 2010.

[15] A. Lehtovuori, M. Honkala, H. Kettunen, and J. Leppävirta, "Interactive engagement methods in teaching electrical engineering basic courses," in *Global Engineering Education Conference (EDUCON), 2013 IEEE*, 2013, pp. 75-84: IEEE.
[16] E. A. Patterson, P. B. Campbell, I. Busch-Vishniac, and D. W. Guillaume, "The effect of context on student engagement in engineering," *European Journal of Engineering Education,* vol. 36, no. 3, pp. 211-224, 2011.
[17] T. Yuen, C. Saygin, H. Shipley, H. Wan, and D. Akopian, "Factors that influence students to major in engineering," *International Journal of Engineering Education,* vol. 28, no. 4, pp. 932-938, 2012.
[18] M. Cargnin-Stieler, M. C. Teixeira, R. M. Lima, D. Mesquita, and E. Assunção, "A contribution for the analysis of pedagogical training for teaching in electrical engineering," *International Journal of Continuing Engineering Education and Life Long Learning,* vol. 26, no. 4, pp. 405-418, 2016.
[19] S. Freeman *et al.*, "Active learning increases student performance in science, engineering, and mathematics," *Proceedings of the National Academy of Sciences,* vol. 111, no. 23, pp. 8410-8415, 2014.
[20] S. Bell, "Project-based learning for the 21st Century: Skills for the future," *Clearing House: A Journal of Educational Strategies,* vol. 83, no. 2, pp. 39-43, 2010.
[21] G. Ladson-Billings, "But that's just good teaching! The case for culturally relevant pedagogy," *Theory into Practice,* vol. 34, no. 3, pp. 159-165, 1995.
[22] L. C. Benson, M. K. Orr, S. B. Biggers, W. F. Moss, M. W. Ohland, and S. D. Schiff, "Student-centered active, cooperative learning in engineering," *International Journal of Engineering Education,* vol. 26, no. 5, p. 1097, 2010.
[23] E. P. Bonner, "Investigating practices of highly successful mathematics teachers of traditionally underserved students," *Educational Studies in Mathematics,* vol. 86, no. 3, pp. 377-399, 2014.
[24] G. Gay, *Culturally responsive teaching: Theory, research, and practice*. New York, NY: Teachers College Press, 2010.