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Relationships Between Engineering Faculty Beliefs and Classroom Practices

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Abstract

This study examines the impact of an NSF-funded professional development program on instructors' attitudes towards, and use of, student-centered learning practices in engineering undergraduate courses. The project launched during spring 2016 and involves promoting communities of practice within engineering disciplines and delivering a series of train-the-trainer workshops to the engineering faculty. The workshops strongly promote tenets of student-centered learning and active engagement practices in the classroom.

As part of the overall program evaluation, multiple assessments were administered throughout the workshop series. Since self-reported practices can be biased, ongoing classroom observations were also conducted to determine actual classroom practices of the instructors. For this study, we focused on the comparison of beliefs about student-centered instruction and observed practices. We provide a point-in-time analysis of the relationship between beliefs and use of active learning practices of the faculty participants in the professional development program.

Beliefs were assessed with the Approaches to Teaching Inventory (ATI). The ATI is a survey that measures the extent of faculty teaching beliefs toward teacher-centered (TC) knowledge transmission vs. student-centered (SC) conceptual change. While the ATI measured beliefs, the degree to which classroom practices were student-centered was assessed via classroom visits by trained observers using the Reformed Teaching Observational Protocol (RTOP). The RTOP is a classroom observation protocol that was designed specifically for STEM classrooms and it allows observers to quantify the degree of student-centered teaching and learning occurring during a lesson.

Results indicated no significant correlations between ATI SC scores and RTOP scores. Correspondingly, no significant relationship existed between average ATI TC scores and overall RTOP scores. However, we did observe significant shifts in attitudes towards student-centered practices through pre- and post-ATI scores comparison. A discussion of the implications of these findings is presented.

Background & Purpose

The traditional lecture format, or teacher-focused/content-oriented instruction, is the primary teaching method used in undergraduate engineering education classrooms.[1] Active learning techniques, or student-centered instruction, involves pedagogical practices that directly engage student participation and activities in the classroom. Research has shown that student-centered teaching strategies are an effective and engaging way for students to learn subject matter.[2]

The backdrop for this research study was an NSF-funded Improving Undergraduate Science Education (IUSE) project at a large college of engineering in the southwestern United States. The IUSE project provides professional development for faculty members from multiple engineering disciplines (including, aerospace, biomedical, chemical, civil, materials, mechanical, and construction engineering). The project utilizes a "train the trainer model" to disseminate the information and to promote student-centered pedagogy in undergraduate engineering courses.

A key part of the project evaluation involved determining the extent of shift in student-centered instruction practices before and after the professional development sessions. This task was accomplished through a pre- and post-assessment survey completed by faculty members and classroom observations. The Approaches to Teaching Inventory (ATI) survey instrument was utilized to measure faculty beliefs towards pedagogical techniques.[3] However, since self-reported practices can be biased, classroom observations were also conducted, which were measured through the Reformed Teaching Observational Protocol (RTOP), to determine actual teaching practices of participants.[4]

For this study, we focused on the relationship between beliefs about student-centered instruction and observed practices. Specifically, this study provides point-in-time analysis of the relationship between beliefs and use of active learning practices in the classroom. As part of the analysis, we looked at beliefs about student-centered learning strategies and at classroom practices at two separate times (one at the beginning of the semester, or start of the professional development series, and one at the end of the semester when the professional development series was ending). The study was framed by the following research question:

> To what extent are faculty beliefs about student-centered strategies reflected in instruction practices in the undergraduate engineering classroom?

Review of Related Research

Student-Centered Teaching in Engineering Education

Student-centered teaching strategies address key course concepts and skills in an engaging and adaptive manner. Many empirical studies have been conducted to better understand the effectiveness of student-centered learning in higher education. These studies have demonstrated that student-centered instruction promotes greater learning and understanding compared to traditional content-oriented strategies.[5,6] This review provides a brief overview of studies that that have examined the efficacy of student-centered learning in STEM education.

Prince reviewed the current literature base on active learning in engineering education.[7] Though Prince did find some studies that did not show a benefit for student-centered instruction, the researcher ultimately concluded that instructors should consider new instruction methods, including active learning practices in their engineering classrooms, as much of the research is compelling regarding the positive results of using student-centered pedagogy in the classroom.

In a meta-analysis of 225 studies, Freeman et. al evaluated instructional methods in undergraduate STEM classes to investigate the impact of active learning on students.[8] Their analysis found that student performance on examinations or concept inventories was higher, at about 6%, with active learning instruction. The authors' analysis also demonstrated that students were 1.5 times more likely to fail a course, if they were enrolled in a traditional lecture class, rather than a class that utilizes active learning teaching principles.

Professional development

Many researchers have focused on change processes in faculty development. Borrego et al. provided a discussion of different change models.[9] They discuss the change process people undergo after learning about new techniques or processes. The authors focus on Rogers' model of diffusion of innovation,[10] which describes a five-stage model for people to adopt an innovation:

1. Awareness or Knowledge - an individual is exposed to an innovation
2. Persuasion or Interest - interest in the subject grows and individuals seek out further information about the innovation
3. Evaluation & Decision - individual either adopts or rejects the innovation
4. Implementation & Trial - innovation is tested by an individual
5. Confirmation or Adoption - individual continues and sustains use of the innovation

Borrego and colleagues utilize Rogers' diffusion of innovation model as a basis for their discussion because this method has been employed frequently by other researchers conducting professional development for faculty members. In general, they found that faculty are likely to progress through the *awareness* and *interest* phases, but rarely move to actual practice or implementation of the innovation. These studies found that it is important for these sessions to provide support and context for implementing the innovation; further it is important to use small group activities to lead to success of the professional development programs.[11,12] Small group sessions provide an option for informal and collaborative learning. Additionally, by utilizing active learning techniques, professional development programs can improve delivery of content and learning of the participants in the program.

In order to be successful, professional development programs need to be flexible to meet the different and changing needs of participants in the program. Further, it is important that the innovation being discussed is successfully implemented into the program.[13] Additionally, the sessions should foster learning via informal and focused interactions that help the practitioners better understand the material.[14]

When scaling an innovation reform, it is important that practitioners see a shift from learning about the innovation to an internal shift where they seek to utilize the particular practice.[15] A key part of this process involves the presenters explicitly stating the benefit of the innovation in the classroom. Ongoing assessment and practices should be utilized throughout the professional development to ensure that participants can advance to this final stage.

Beliefs & Teaching Practices

Faculty beliefs about teaching and learning play a critical role in shaping teaching practices in the classroom (Pajares, 1992).[16] Much of one's beliefs about education and teaching is drawn largely from what they already know and have observed in classrooms when they were students.[17] Thus, since the traditional lecture format has been the dominant form of teaching in engineering classrooms, faculty continue to learn teacher-oriented pedagogical strategies in the classroom.[18] However, the relationship between instructors' beliefs and practices is complex and not linear.[19]

There are conflicting findings in the literature about the link between beliefs about teaching and actual classroom practices. Many researchers have found that beliefs about teaching or learning strongly influence classroom practices.[20, 21] These studies have found a positive connection or correlation between teacher beliefs and actual classroom practices.

Whereas, other researchers have found that espoused beliefs and practices of faculty members are not aligned with actual teaching practices in the classroom.[22] Further research has demonstrated that faculty beliefs about teaching are dependent on multiple factors, including gender, years teaching, discipline, academic and social contexts.[23, 24]

The conflicting findings in the literature point to a further need for more research to better understand the relationship better understand the connection between beliefs and practices. This study aims to contribute to this gap by examining the relationship between beliefs and practices regarding student-centered teaching strategies in undergraduate engineering classrooms.

Methodology

This IUSE project aims to increase awareness of student-centered practices in the classroom. By increasing awareness, the project aims to shift faculty beliefs about pedagogical practices and encourage faculty to employ these active learning strategies in the classroom. In order to achieve this goal, the project consists of an 8-week professional development series. Each workshop has a different topic of focus, but they all center around student-centered learning practices and inclusion in the classroom.

The project utilizes a "train the trainer" model to disseminate the information. For the first year of the project 8 faculty members were recruited in pairs from 4 disciplines. The initial group of faculty, or cohort 1, then became Disciplinary Leader Pairs (DLPs), who then trained another group of faculty members from their own discipline. Table 1, below, provides an overview of the project timeline.

Table 1. Project Overview and Schedule.

	Cohort 1 Tier 1 Disciplinary Leader Pairs	Cohort 1 Tier 2 Disciplinary Faculty Groups	Cohort 2 Tier 1 Disciplinary Leader Pairs	Cohort 2 Tier 2 Disciplinary Faculty Groups
Year 1 *Fall 2015 - Spring 2016*	Being trained by Project Leaders & classroom implementation			
Year 2 *Fall 2016 - Spring 2017*	Teach Sessions to Tier 2 DFGs	Being trained by Cohort 1 Tier 1 DLPs	Being trained by project leaders & classroom implementation	
Year 3 *Fall 2017 - Spring 2018*	Ongoing assessment	Ongoing assessment	Teach sessions to Cohort 2 Tier 2 DFGs	Being trained by Cohort 2 Tier 1 DLPs
Year 4 *Fall 2018 - Spring 2019*	Ongoing assessment	Ongoing assessment	Ongoing assessment	Ongoing assessment

Sample & Administration

The sample for this project came from the IUSE project at a large southwestern university in the United States. Participants in the IUSE professional development program were recruited from the college of engineering. Faculty were invited to participated via email solicitation from department leadership and via personal referrals from the project team members.

For this study, the sample is comprised of individuals form cohort 1 – tier 2 and cohort 2 – tier 1, to provide a point-in-time analysis of attitudes towards and use of active learning strategies in the classroom. Thirty-five total faculty members participated in workshops during the Fall 2016 semester. The faculty members came from seven departments in the college of engineering: aerospace, biomedical, chemical, civil, materials, mechanical, and construction engineering.

As part of the overall program evaluation, pre- and post-assessments have been or will be administered throughout the workshop series. Because self-reported practices can be biased, classroom observations were also conducted to determine actual teaching practices of the instructors in the classroom. For this study, we focused on the comparison of beliefs about student-centered instruction and observed practices.

The Approaches to Teaching Inventory was utilized to assess faculty beliefs about pedagogical strategies. The ATI was administered before the start of the professional development workshops. A post-assessment was also completed by participants during the final week of the professional development workshops.

To quantify classroom practices of faculty participants, classroom observations were conducted utilizing the Reformed Teaching Observation Protocol. Two classroom observations per faculty member were conducted during the Fall 2016 semester. In order to validate observations and findings, two people completed the RTOP form during each observation. Results were then compared and discussed for comparison and validation after the observation. The ATI and RTOP instruments are described in greater detail in the section below.

Instruments

Approaches to Teaching Inventory (ATI)

The Approaches to Teaching Inventory is a self-reporting instrument that measures faculty perceptions about their own teaching practices in the classroom.[25] The twenty-two item survey examines faculty teaching beliefs toward the extent of faculty teaching beliefs toward instructor-centered knowledge transmission vs. student-centered conceptual change. In order to assess these beliefs, respondents are asked to rate items on a 5-point Likert scale (strongly disagree to strongly agree).

The ATI is comprised of four constructs to assess faculty beliefs about classroom practices. The instrument was designed to assess approaches to teaching and the underlying intentions of using those strategies. Two of these constructs are focused on teacher-centered (TC) strategies and the other two center on student-centered (SC) teaching strategies. The four intentions are:

> *Information transmission (TC):* These items focus on the extent to which the instructor emphasizes sharing information with the students in the class.
>
> *Teacher-centered strategies (TC):* The items in this dimension emphasizes the extent to which instructors utilize pedagogical strategies that are content-oriented, such as the traditional lecture format.
>
> *Student-focused strategies (SC):* These items measure the extent to which faculty members use active learning strategies in the classroom.
>
> *Conceptual change (SC):* The items in this construct measure the extent to which instructors are aware of student development in the class. This includes support of student development in the class.

Reformed Teaching Observation Protocol (RTOP)

The Reformed Teaching Observational Protocol (RTOP) is a classroom observation tool that quantifies the extent to which faculty utilize student-centered behaviors in their teaching practices.[26] During classroom observations, observers completed the RTOP instrument to assess faculty teaching practices.

The RTOP is comprised of 5 dimensions, each of which is comprised of five questions. Observers rate faculty members' practices of each item on a five-point Likert scale (never occurred to very descriptive). The five constructs are comprised of the following components:

Lesson design & implementation: These items focus on structure and delivery of the class materials. For example, it assesses whether instructors' draw on prior knowledge and the role of students in the learning process.

Propositional knowledge (content): This construct examines how course material is presented in the class. More specifically it looks at subject matter being taught, including instructor understanding and if the lesson included key fundamental concepts.

Procedural knowledge (content): This dimension assesses how students engage with course subject. For instance, the items address if students use multiple methods to represent the phenomena being taught or if they are reflective about their learning.

Communicative interactions (culture): These items focus on the types of interactions that occur in the classroom. Specifically, it assesses if the classroom culture is inclusive and the types of communication that are facilitated in the classroom.

Student/teacher relationships (culture): This final construct examines the relationship between students and teachers in the classroom. For example, if the teacher encouraged active participation and if the teacher was patient with students in the class.

There were 4 people who conducted observations. Two of the observers were education professionals, both who had substantial teaching experience and education research backgrounds. The other two observers were students with engineering backgrounds. All of the observers went through training on this instrument from a team member who was involved in the development of this instrument. The person who was responsible for training has conducted many training sessions for RTOP. During the RTOP training the observers reviewed all of the items and dimensions for clarity. Practice RTOP observations were also conducted. After the practice sessions, observers would review their scores and compare to understand reliable ratings.

Classroom observations were conducted in pairs, one student with one of the education professionals. After the observations, each pair would go through each item to compare scores. Any differences in ratings were discussed and each team would come to a consensus on individual item scores.

Data Analysis

Since not all of the faculty members completed both a pre- and post-ATI survey, we omitted cases where we did not have both pre- and post-ATI data. In total, this left 25 total cases with complete data for analysis.

The analysis in this study was focused on faculty attitudes towards and use of teaching strategies in the classroom. First, we wanted to understand if self-reported beliefs about and use of strategies shifted at all during the professional development sessions. Additionally, we wanted to determine if faculty beliefs about student-centered learning strategies correlated to actual implementation of active learning practices in the classroom.

Results

Beliefs towards Student-Centered & Teacher-Centered Learning Strategies

In order to assess beliefs towards teaching strategies, teacher-centered and student-centered scores were constructed for all ATI respondents. These scores were computed for both pre- and post-ATI assessments. Total points possible for TC and SC dimensions were 40, with a total number of 80 points possible on the overall ATI score. A summary of these scores is presented in table 2, below.

Table 2. ATI Pre- and Post-Assessment Mean, Standard Deviation, & Change.

	Teacher-Centered	**Student-Centered**	**ATI Total**
	Mean (SD)	*Mean (SD)*	*Mean (SD)*
Pre	17.435 (5.212)	20.957 (4.548)	38.391 (8.228)
Post	25.304 (4.322)	27.348 (4.969)	52.652 (5.773)
Change	7.870	6.391	14.261

A paired samples t-test was conducted to explore if the pre- and post-ATI scores were significantly different. The results demonstrated that the overall ATI score, TC score, and SC scores were significantly different from pre- and post-professional development. The average TC post-score was significantly higher than the pre-score, with an overall change of 7.8695 points (t_{22}= 6.973, $p < 0.05$, CI= 5.532, 6.983). The average SC post-score was also significantly higher than the average pre-score, with an overall change of 6.3913 points (t_{22}= 4.741, $p < 0.05$, CI= 3.596, 9.187). Finally, the average ATI-post score was also significantly higher than the average pre-score (t_{22}= 7.667, $p < 0.05$, CI= 10.404, 18.118).

The results indicate that there was a significant shift in faculty beliefs towards student-centered learning strategies after the professional development sessions. However, it is also interesting to note that there was also an increase in attitudes towards teacher-centered strategies, which is surprising given the increase in SC beliefs. This finding may be a result of a general or overall increase in awareness of teaching practices and strategies, and thus a shift in attitudes towards all practices.

Next, a paired sample t-test was conducted to explore differences in attitudes towards TC and SC strategies. Pre-TC & SC average scores were compared, and then post-TC & SC scores. The paired samples t-test for the pre-ATI scores revealed that there was a significant difference in beliefs about SC and TC practices (t_{22}= -3.193, $p < 0.05$), CI= -5.809, -1.234). This indicates that at the start of the professional development workshops, the faculty members did hold significantly different attitudes towards teacher-centered and student-centered teaching strategies. However, the second test revealed that there was not a significant difference in post-

TC and SC average scores (t_{22}= -1.341, $p > 0.05$, CI= -5204, 1.117). This finding is surprising, as we would expect that difference in attitude would grow from the first pre-test, or at the very least resemble the difference in the first ATI pre-test.

Pedagogical Practices in the Classroom

Classroom observations were conducted, via the RTOP, to assess classroom practices of the faculty participants. Two RTOP observations were conducted for each faculty member. RTOP1 score and RTOP2 score variables provide a quantifiable measure of use of active learning practices in the classroom. An average RTOP score was created by combining RTOP 1 & 2 scores, to assess general classroom practices in the fall 2016 semester. Table 3, below, provides a summary of these three variables.

Table 3. RTOP Scores Summary.

Score	**Mean**	**Standard Deviation**
RTOP 1	53.630	17.581
RTOP 2	54.643	16.250
RTOP Average	55.071	12.967

The RTOP 1 and RTOP 2 scores were compared to determine if there was a significant shift in active learning practices in the classroom. The results indicated that there was no significant difference in RTOP scores (t_{20}= 0.185, $p > 0.05$, CI= -8.803, 10.517).

Relationships Between Beliefs & Practices

Pearson correlation analysis was then conducted to explore the relationship between attitudes towards classroom practices and classroom implementation of student-centered learning practices.

In order to conduct these analyses, several different variables were tested to assess these relationships. ATI pre-scores were constructed for both TC and SC beliefs. Post-scores of TC and SC beliefs were also created from the post-ATI assessment. These scores were also averaged to create an overall estimate of SC & TC beliefs in the fall 2016 semester.

Pearson correlation analyses revealed no significant correlations between TC & SC scores and RTOP scores ($p > 0.05$). This was the case for pre-TC, pre-SC, post-TC, post-SC, RTOP 1, RTOP 2, RTOP average, and ATI average.

Discussion

The results indicated some expected and some surprising results. There was no significant relationship between ATI SC scores and RTOP scores. This result is surprising, as we would have expected at least some correlation between beliefs about the efficacy of student-centered practices and implementation of these strategies in the classroom. One possible reason for this is that the SC scores and RTOP scores were not particularly high, thus they would not be highly correlated. However, it would have been expected to see a negative correlation then between the

TC scores and the RTOP scores, indicating a strong disposition towards teacher-centered content and with low levels of active learning being implemented in the classroom.

What was more revealing in this analysis was shifts in attitudes of the faculty members pre- and post-professional development. Attitudes towards both TC and SC teaching practices were significantly different before and after the professional development sessions. Attitudes towards SC teaching attitudes increased, as expected. However, we also observed an increase in dispositions towards TC practices, which was surprising given the content of the program emphasized moving away from these practices. The next finding confirmed that at the start of the professional development program the instructors had significantly different attitudes towards TC and SC practices, but the post-test found that faculty members had the same views towards TC & SC practices at the end of the program.

One possible reason for the lack of correlation between ATI SC scores and RTOP scores is that the disconnect between espoused beliefs and actual practices. Faculty may think that they value and utilize active learning strategies in the classroom, when in fact, they do not. This disconnect is a common occurrence in education research. Further participation in faculty development programs will likely lead to a deeper understanding of SC teaching practices and how they are implemented in the classroom.

This study provides a point-in-time, mid program, analysis of the professional development program. The data analyzed in this study comes from faculty members who have only been in the program for one semester. As Borrego et. al[27] and discuss, changing pedagogical practices is a difficult and timely process. Additionally, when it comes to new innovations, many people are quick to change their attitude and interest in something, but it is rarer for people to advance to actual implementation.[28] Therefore, part of what we are observing is likely that participants in the program have experienced a shift in attitude, but have still not advanced to the implementation phase. Further observations will be conducted during the Spring 2017 semester and Fall 2017 semesters. This data will be analyzed to better understand these patterns. This data will likely reveal a correlation between ATI SC scores and RTOP practices, if faculty have begun to increase implementation of SC teaching practices.

The findings from this study have several implications for universities, those involved in professional development programs, and researchers. First, they point to a need for further research and analysis to better understand the connection between practices and beliefs. Further research should also be conducted to better understand the possible correlation and relationship between ATI SC scores and RTOP scores, in order to see if it is similar to the lack of correlation found in this study. The findings from this study affirm general trends in the literature about the challenges of advancing innovations from the interest or awareness phase into actual implementation. When developing professional development programs, people should consider this challenge. Further, they should include dedicated and structured time for program participants to discuss about the particular innovation that the program is focused on, in order to help facilitate change of practices.

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