

Is There a Connection Between Classroom Practices and Attitudes Towards Student-Centered Learning in Engineering?

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Background & Purpose

This study developed from a larger NSF-funded Improving Undergraduate Science Education (IUSE) project at a large college of engineering in the southwestern United States. This IUSE project, Scaling a Cyber-Enabled, Just-in-Time-Teaching with Two-Way Formative Feedback (JTF) Project from the Individual Faculty Level to the Disciplinary Department Program Level (JTFD), provides professional development for faculty members across multiple engineering disciplines: aerospace, biomedical, chemical, civil, construction, materials, and mechanical. The project promotes student-centered pedagogical practices in undergraduate engineering courses.

As part of the JTFD project evaluation, a series of pre- and post-assessments and measures were taken to better understand faculty shifts due to the professional development program. Faculty members completed multiple surveys before and after participating in the IUSE program. Since self-reported measures can be biased, we also conducted classroom observations to characterize implementation of active learning strategies in the classroom. A more detailed discussion of the survey and classroom observation protocol utilized in this project is provided in the methodology section.

This study is focused on the relationship between attitudes towards student-centered instruction and observed practices. Specifically, this study provides a point-in-time analysis of the relationship between beliefs and use of active learning pedagogical practices in the classroom. We looked at beliefs and practices from two separate times: one at the beginning of the professional development program (fall 2016), and the other at the end of the semester after the workshops (spring 2017). This study was framed by the following research question:

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

Literature Review

Student-Centered Teaching in Engineering

Student-centered teaching, or active learning practices, engage key course concepts and material in an adaptive and interactive manner. Scholars have conducted many empirical studies which demonstrate the effectiveness of student-centered teaching practices in higher education. These studies have shown that student-centered instruction promotes greater learning and understanding than traditional content-oriented teaching strategies [1], [2]. After a review of current literature, Prince concluded that engineering faculty should consider new instructional methods, including active learning strategies, in their classrooms, as he found compelling evidence regarding the efficacy of student-centered teaching practices [3].

In a meta-analysis of 225 studies, Freeman et al. evaluated instructional practices in undergraduate STEM classes to better understand the impact of active learning on students [4]. The authors found that student performance on examinations or concept inventories was higher, approximately 6%, with active learning instruction. Further, their analysis demonstrated that students were 1.5 times more likely to fail a course if they were enrolled in a traditional lecture class, instead of a class that employs student-centered teaching practices. Ultimately, the current literature base shows compelling analysis that student-centered teaching practices have merit and are an effective way to teach students.

Professional Development

Researchers have focused on change processes within faculty development. Borrego et al. discuss the change process people undergo when learning about new techniques or models [5]. Within their research, the authors draw on Rogers' model of diffusion of innovation, which describes a five-stage model for people to adopt an innovation [6]:

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

Rogers' diffusion of innovation model has been commonly used by researchers examining faculty professional development in higher education. Borrego and colleagues found that faculty frequently progress through the *awareness* and *interest* phases, but rarely advance to practice or implementation of the innovation [7]. Therefore, other researchers have found that it is critical to provide support and context, such as small group activities, to faculty members when trying to promote implementation of new teaching innovations [8], [9]. Additionally, by utilizing active learning techniques, professional development programs can improve delivery of content and learning of the participants in the program.

Several other factors have been identified as important traits of successful professional development programs. First, the program needs to be flexible to meet the various and shifting needs of faculty participants. Further, the innovation being covered in the professional development should be implemented into the program [10]. The professional development sessions should cultivate learning environments through informal and targeted interactions which enhance the practitioners' understanding of the topics being discussed [11]. Finally, it is important that faculty participants see a shift from learning about the innovation to seeking out how to implement that strategy in the classroom [12].

Beliefs & Teaching Practices

Faculty beliefs about teaching and learning play a key role in shaping teaching practices in the classroom [13]. Faculty beliefs about teaching tend to be related to what they already know and experienced in classrooms when they were students [14]. Therefore, since the dominant form of teaching in engineering classrooms has been the lecture format, faculty tend to continue to utilize teacher-oriented pedagogical strategies in their own classrooms [15].

Despite these general trends, the relationship between teaching beliefs and actual practices is complex and not always linear [16]. Further, there are conflicting findings in the literature about the link between beliefs about instruction and pedagogical practices. Many researchers have found a strong link between instructional beliefs and practices [17], [18]. Other researchers have found that espoused beliefs do not align with faculty members' practices [19], [20]. Ultimately, research shows that faculty beliefs about teaching are related to multiple factors, including gender, years of teaching, discipline, as well as, social and academic contexts [21], [22].

These conflicting findings point to the need for more research to better understand the more nuanced relationships between beliefs and practices in the classroom. This study aims to expand the current literature by examining the relationships between beliefs and practices regarding active learning teaching strategies for engineering faculty members in undergraduate classrooms.

Methodology

The backdrop for this study is the JTFD professional development (PD) program funded through the NSF IUSE grant program. This IUSE project aims to increase awareness of student-centered, or active learning, teaching practices in the classroom. Through increasing awareness of these pedagogical practices, the project aims to shift faculty beliefs about active learning and traditional teaching methods in undergraduate engineering classrooms. The core training consists of a semester-long biweekly professional development series. Each of the eight sessions of the PD program consists of a workshop focused on a different topic related to active learning and inclusion in the classroom.

The IUSE project utilizes a "train the trainer" model to disseminate information. For the first year of the project pairs of faculty members were recruited from four engineering disciplines. The following semester, these pairs of faculty members became Disciplinary Leader Pairs (DLPs) who delivered workshop materials to next group of faculty members from their own discipline. After that, the DLPs facilitated communities of practice (CoPs) during the following semester with their discipline-based faculty. This process was repeated with a second cohort one year after the start of the project as depicted in the project timeline (Table 1).

Table 1. JTFD Project Overview and Schedule.

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

Sample & Administration

The JTFD professional development program occurred at a large southwestern university in the United States. Participants in the professional development program were all faculty members in the college of engineering, across seven sub disciplines. Participants were recruited into the professional development program through an email from department leadership and personal referrals from project team members.

This study focused particularly on individuals from cohort 1, tier 2, and cohort 2, tier 1, to gain a point-in-time understanding of attitudes towards and use of active learning strategies in the classroom. Thirty-eight faculty members participated in the project in the Fall 2016 semester. However, complete data existed for only 21 faculty members, so analysis is restricted to those cases.

Program evaluation consisted of pre- and post-assessments and classroom observations throughout the professional development series. Evaluation included self-reported data about beliefs towards, and use of, classroom practices. Classroom observations were conducted to gain a deeper understanding of actual teaching practices implemented in the classroom because self-reported practices can be biased. This study focused on two particular measures: self-reported beliefs about teaching assessed through the Value, Expectancy, & Cost of Testing Educational Reforms Survey (VECTERS) and observed classroom practices measured by the Reformed Teaching Observation Protocol (RTOP).

Instruments

Value, Expectancy, and Cost of Testing Educational Reforms Survey (VECTERS)

To assess faculty dispositions towards, and use of, specific active learning strategies, the Value, Expectancy, and Cost of Testing Educational Reforms Survey (VECTERS) was utilized [23]. VECTERS measures dispositions towards, as well as current and planned use of, three active learning strategies:

- (1) Using *formative feedback* to adjust instruction
- (2) Integrating *real-world applications*
- (3) Facilitating *student-to-student discussions* in class

VECTERS prompts respondents to consider each strategy and consider the degree to which they (a) expect the strategy to be successful, (b) find it valuable, and (c) believe it is costly (e.g., time, resources). The survey measures attitudes towards these practices, along three constructs:

Expectancy: This construct examines expectation of what will happen in the learning environment when a specific teaching strategy is implemented. These items focused on perceived outcomes, either successful or unsuccessful. The items related to three areas of focus for expectation of success: students' abilities, instructor capabilities, and the physical setup of the classroom.

Value: The value construct is closely related to benefit. The value items focused on determining if respondents viewed each strategy as having either a beneficial or detrimental impact for students or instructors.

Cost: The cost items measured perceived expenses for implementing each strategy. The cost items addressed preparation time, use of teaching assistants, and effort required for utilizing that strategy.

VECTERS is comprised of 11 value items, 10 expectancy items, and 5 cost items, for 26 total items. Respondents were asked to respond to each item to indicate their level of agreement on a four-point Likert scale. Faculty responded to each set of items for the three classroom strategies, resulting in 78 total items.

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 [24]. Trained observers attended class sessions of faculty members and completed the RTOP to indicate implementation of student-centered strategies in the classroom.

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.

Four team members conducted classroom observations, two were students with engineering backgrounds and two were educational professionals with substantial teaching and instructional coaching experience. All observers went through training on the RTOP instrument from a team member who was involved in the development of the protocol.

Classroom observations were conducted in pairs, one student with one of the education professionals. After the observations, each pair reviewed the RTOP scores, item by item, for each class session. Any differences in scores were discussed and the pairs would come to a consensus on individual item ratings. Two observations were conducted in the fall semester, and serve as pre-observation data. For this study, we focused our analysis of two observations conducted at the end of the spring semester, which serves as post-observation data.

Data Analysis

Cases were restricted to faculty members who completed both pre- and post-VECTERS and classroom observations. This left 21 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, particularly active learning pedagogical practices. First, we examined if self-reported beliefs or use of active learning practices shifted at all over the course of the

professional development program. Next, we analyzed the relationship between faculty beliefs and implementation of student-centered teaching practices in the classroom.

Results

Beliefs Towards Different Teaching Strategies

Data from VECTERS were initially analyzed individually to assess changes over the course of one academic year, in which participants ($n = 21$) were enrolled in the professional development program. Paired samples t-tests were conducted on expectancy, value, and cost beliefs for each of the three classroom strategies (see Table 2) to assess changes in beliefs before and after participating in the professional development program.

Table 2. VECTERS Pre- and Post-Assessment Mean Change ($n=21$).

	Mean Change	Significance (p)
Expectancy		
Formative feedback	+ .281	.012
Real-world applications	-.064	.609
Student-to-student discussions	-.017	.228
Value		
Formative feedback	+ .303	.017
Real-world applications	+ .478	< .01
Student-to-student discussions	+ .216	.180
Cost		
Formative feedback	+ .083	.700
Real-world applications	-.508	.022
Student-to-student discussions	-.300	.304

Analysis of pre- to post-VECTERS indicated several significant changes ($p < .05$) in faculty attitudes towards the three active learning strategies. Overall, we found significant increases in expectation of success of formative feedback and value of formative feedback and real-world applications ($p < .05$). A decrease in cost of real-world applications was also observed ($p < .05$).

These results indicate that there were several positive changes in attitudes and a decrease in the perception of barriers (i.e., cost) regarding expectation of success and value of student-centered teaching strategies, particularly for formative feedback and real-world applications.

Instructional Practices

We then analyzed changes in instructional practices. First, we looked at self-reported use of active learning strategies from VECTERS. Then we analyzed data from RTOP to measure change in observed classroom practices.

Self-reported use of practices, at pre- and post-time points, were measured through VECTERS. The VECTERS instrument prompted respondents to rate current and planned future use of each of the three instructional strategies. Paired sample t-tests were conducted to assess changes in reported current and planned future use of the teaching practices (see Table 3). Analysis

indicated significant ($p < .05$) changes in current (12%) and planned (15%) use of real-world applications in their classroom practices. However, the reported current or planned future use changes for both formative feedback and student-to-student discussions were not significant ($p > .05$).

Table 3. Changes in Current and Planned Use of Instructional Practices (n=21).

	Mean Change	Significance (p)
Use Now		
Formative feedback	-.143	.500
Real-world applications	+.429	.028
Student-to-student discussions	.000	1.00
Use Later		
Formative feedback	+.071	.720
Real-world applications	+.571	.040
Student-to-student discussions	-.143	.583

Next, we examined change in classroom practices from RTOP data collected during classroom observations. A summary of average RTOP scores from Fall 2016 to Spring 2017 is reported in Table 4.

Table 4. RTOP Scores Summary. (RTOP scale from 0 to 100)

Score	Mean	Standard Deviation
Fall 2016	58.448	14.769
Spring 2017	68.979	12.057

In order to assess the changes in classroom practices, a paired samples t-test was conducted to compare pre- and post-RTOP scores from Fall 2016 to Spring 2017. The results indicated there was a significant increase in RTOP scores ($t_{24} = -3.589$, $CI = -16.602, -4.461$, $p < .01$). These results demonstrate a positive shift in actual implementation of active learning strategies in the classroom.

Relationships Between Beliefs & Practices

This study focused on comparing beliefs about student-centered instruction (as measured by VECTERS) and observed practices (as measured by RTOP). To analyze these relationships, Pearson correlations were conducted between reported expectation of success, value, and cost of each of the three strategies, and overall RTOP score. We then conducted Pearson correlations between specific RTOP items associated with the three strategies measured on RTOP. Finally, we conducted Pearson correlation analysis for reported use of the strategies and observed RTOP scores.

Formative feedback expectancy was positively and significantly correlated to mean RTOP scores ($p < .05$), while perception of the cost of integrating formative feedback in the classroom was negatively correlated with mean RTOP scores ($p < .05$). This negative relationship indicates faculty who were observed to be integrating high levels of student-centered strategies were more inclined to report the integration of formative feedback as having a low cost of implementation.

To further explore the relationships, we examined individual constructs on the RTOP, which corresponded to specific strategies from VECTERS. As expected, some of these strategies were significantly correlated with specific RTOP constructs. Specifically, we looked at one item from the propositional knowledge construct and one from the lesson design and implementation construct. The specific items from each section are:

Lesson Design & Implementation #5: *The focus and direction of the lesson was often determined by ideas originating with students.*

Propositional Knowledge #5: *Connections with other content disciplines and/or real world phenomena were explored and valued.*

The lesson design & implementation item was tested with the constructs related to formative feedback from VECTERS. Whereas the propositional knowledge item was tested with the constructs related to real-world applications from VECTERS. In both cases, we measured the relationship between these items using Pearson correlation analysis. We found significant, positive relationship between expectation of success for real-world applications and the propositional knowledge item from RTOP ($r = .463, p < .05$). The perceived cost of real-world applications and propositional knowledge item on the RTOP were also significantly correlated, but we observed a negative relationship ($r = -.526, p < .05$). A significant, positive relationship was found between value of real-world applications and propositional knowledge factor score from the RTOP ($r = .649, p < .01$).

Participants reported use of student-to-student discussions was highly, and positively correlated with RTOP scores during the fall semester ($r = .522, p < .05$), which indicates a connection between perceived beliefs/use and actual implementation. Reported use of the three strategies and observed RTOP scores were not significantly related for the Spring 2017 semester.

Discussion

The results from the analysis indicated both expected and surprising results. As expected, we did observe shifts in faculty beliefs about student-centered teaching practices. Given the emphasis on active learning practices in the professional development program, the positive shift in attitudes towards these practices was expected. Faculty shifted in terms of value and expectation of success for real-world applications and formative feedback. We also observed an increase in use of student-centered practices in faculty teaching, as measured by the RTOP. Average faculty RTOP scores increased 10 points from the fall 2016 to spring 2017 semester, or from before and after the professional development workshop. Both of these findings are promising and encouraging results that indicate the success of the professional development program, and the potential link teaching beliefs and practices.

The analysis to assess the relationship between beliefs and practices was less conclusive. A few significant relationships were observed. Formative feedback and RTOP scores were positively related. We observed a positive relationship between expectation of success for formative feedback and RTOP scores, indicating beliefs about expecting the use of formative feedback and levels of student-centered practices was correlated. We also found a negative relationship

between perceived cost of formative feedback and RTOP scores, which indicates that low perception of cost of this strategy was associated with using student-centered teaching strategies. A number of specific RTOP items were significantly correlated with some of the constructs for the three strategies from VECTERS. For instance, we found a positive relationship between value of real-world applications and propositional knowledge scores from RTOP. Significant relationships were also found for reported use of student-to-student facilitated discussions and RTOP scores in the fall semester. However, we did not observe any other significant relationships between reported use and actual use of the practices.

These findings are promising in that we did observe relationships between some reported beliefs and use of active learning practices. This aligns with some findings in the literature, which indicates a connection between beliefs and practices. Though we did find some consistencies between the two, we did not find significant relationships between all constructs and RTOP scores. This could be because there is some level of disconnect between beliefs and practices. In the diffusion of innovation model, there are a number of stages from learning about a practice before adoption or implementation of the strategy; faculty may still be going through the change process and working towards integrating active learning practices more thoroughly in their classrooms.

This study provides a point-in-time analysis of the professional development program, which is still ongoing. The data analyzed in the study comes from faculty across one year. As Borrego et al. discuss, faculty change is an ongoing process, especially for shifting pedagogical practices [25]. Therefore, faculty may be more likely to shift their beliefs, before changing their classroom practices. Further assessment and ongoing analysis will be conducted as part of the program evaluation. Future analysis will be more telling about the link between beliefs and practices for faculty who participated in the professional development program.

The findings from this study have important implications for universities, those involved with professional development programs, and researchers. First, the results point to a need for further research and analysis to better understand the complex relationship between teaching beliefs and practices. The findings from this study point to the link between practices and espoused beliefs. However, as observed in the literature, we also observed a complicated, and non-linear relationship between teaching practices and faculty beliefs. When building professional development programs, people should consider these challenges and be aware of the complicated relationship between practices and beliefs. Further, professional development programs should include dedicated time for participants to discuss innovations and teaching practices, as this is an important part of the change process, and will help foster shifts in use of active learning practices for faculty members.

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