Instructional practice learning through Instructional Incubator engagement

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***Abstract**: While student-centered learning has been shown to improve learning experiences in the engineering classroom, adoption of these evidence-based strategies has been slow. Research has shown that faculty beliefs about teaching and limited exposure to formal training influence effective implementation of evidenced-based instructional practices. Thus, in an effort to explore ways to implement long-term instructional change in engineering higher education, a graduate-level course, the Instructional Incubator (I2), was developed to expose future educators to instructional design and evidence-based practices. In the I2, student participants developed new biomedical engineering short-courses in an active learning classroom. For the first two iterations of the I2, we examined how this immersive experience influenced participants' perceived teaching abilities and understanding before and after enrolling in the I2. Both I2 cohorts reported an increase in knowledge of engineering education related terms and showed a shift away from behaviorist and cognitive beliefs about teaching and learning.*

Introduction

Increasing evidence supports the need to change instructional practice in science, technology, engineering, and math (STEM) classrooms to improve student learning (M. Smith, Jones, Gilbert, & Wieman, 2013; Stain et al., 2018). One strategy gaining traction in engineering educational practice is the shift to student-centered learning (Stain et al., 2018), which works to increase student-to-student and student-to-instructor interaction and cognitive engagement using various classroom strategies, such as active learning pedagogies (e.g. flipped classroom, think-pair-share, project based learning). However, the transition to student-centered engineering classrooms is still limited (Kim, Speed, & Macaulay, 2019; Nguyen et al., 2017). This may be due in part to individual instructor beliefs about teaching (Borrego, Froyd, Henderson, Cutler, & Prince, 2013) and limited formal training available to new faculty on evolving strategies for implementing student-centered learning (Brownell & Tanner, 2012; Burd et al., 2016). Studies seeking to understand the disconnect between instructor beliefs and the subsequent implementation of evidence-based practices have shown that creating a community for faculty to engage in pedagogical change may improve the implementation of evidence-based practices in classrooms (Shekhar & Borrego, 2017).

Recognizing that graduate students will play a critical role in long-term instructional change and are currently taking on more teaching roles as students (Austin, 2007; Smith, Sitomer, & Koretsky, 2014), efforts are being made to examine graduate student adoption of student-centered, evidence-based teaching practices (Goodwin, Cao, Fletcher, Flaiban, & Shortlidge, 2018). Goodwin et al.'s 2018 study of biology graduate students found that graduate students that adopt evidence-based teaching practices may be playing a role in changing the culture of teaching practices on campuses. At the same time, while the majority of the graduate students showed an interest in evidence-based teaching practices, they were disappointed in the quality of support they were receiving for developing their teaching skills.

Looking to graduate students as the change agents for long term instructional change, we developed a structured, biomedical engineering (BME) graduate level course for students to develop their teaching skills, the Instructional Incubator (I2). The I2 addresses two challenges that have been identified as barriers to instructional change by 1) creating a community for individuals interested in pedagogical change (students, postdocs, and faculty) to engage in change together and 2) providing structured support for graduate students to develop courses and integrate evidence based practices as future engineering educators. The purpose of this research into practice study is to examine how participation in the research-based I2 influences participant perceptions of teaching and learning. Specifically, we explore student participant knowledge of, ability in, and beliefs on teaching and learning. We ask the following research questions:

1. How does participant knowledge of and ability in teaching and learning change as indicated by quantitative self-report survey data?
2. How do participant beliefs about teaching and learning change?

Background

The Instructional Incubator (I2)

The I2 is the first semester of a two-semester, graduate level sequence (I2-Module Sequence). In the two-semester sequence, graduate students, upper level undergraduates, post docs, and faculty create and implement 1-credit BME-in-Practice Modules (Malaga, Nu, & Huang-Saad, 2018). The Modules target first and second year students to engage them in BME practice early in their academic career.

The I2, offered in the fall semester, is an experiential course where participants learn about student learning theory and curriculum design, while developing their own modules through the instructional design process. Participants collectively discuss evidence-based pedagogical practices in engineering education and advances in learning theory. For the instructional design process, participants engage in “Instructional Discovery” (ID) where they interview BME stakeholders (e.g. BME undergraduates, practicing biomedical engineers, instructors) and learn about the current state of BME in practice. This process includes focusing on problems of the field, cutting edge research used to solve these problems, professional practice standards, current technical tools used, and industry standards and vocabulary. Integrating what they experience in the classroom and the student learning literature, participants form teams and use the needs identified by stakeholders to create 1-credit (4 week) “BME-in-Practice” modules. Participants have the option to team teach their “BME-in-Practice” modules in the following winter semester with guided mentorship.

Instructional Incubator’s Motivation and Theoretical Grounding

The creation of the I2 was motivated by calls to transform undergraduate education. (American Society for Engineering Education, 2013; National Academy of Engineering, 2013). Research around implementation of student-centered learning strategies in engineering classrooms has shown positive results for students (Mostrom & Blumberg, 2012). Of those student-centered learning strategies, active learning (AL) has been shown to be particularly efficacious (Christie & Graaff, 2017; Freeman et al., 2014). AL approaches have been shown to increase student engagement in the classroom, increase average grades and pass rates, deepen student understanding of course material, promote self-efficacy, and increase student confidence in their abilities (Kim et al., 2019; Marone et al., 2018). Although it is apparent that AL benefits students, instructors often have difficulties implementing these strategies. These difficulties could be partially attributed to a number of factors. In STEM courses, the most commonly implemented education practice is lecturing, where students passively listen while the instructor speaks (Kim et al., 2019). Many of today's academics were educated in this style when they were going through their coursework (Kim et al., 2019) and excelled in this environment. Faculty therefore, often retain this status quo in teaching in addition to citing lack of training and time as barriers for implementing new teaching practices (Kim et al., 2019).

By creating a space for participants to experience curricular change through the student-centered learning strategies used in the I2 and then subsequently implement curricular change in their Modules, the course sequence employs the tenets of situated learning theory's communities of practice (Wenger, Mcdermott, & Snyder, 2002) and constructivism (Newstetter & Svinicki, 2011). Additional research suggests that it is possible to bring about instructional change by changing instructors' beliefs about teaching and learning to better align with the intentions of research-based reforms (M Borrego et al., 2013; Kember, 1997). One effective way for changing beliefs is creating opportunities for instructors to experience research-based practices while in a student role to internalize the benefits of these practices (Fetters et al., 2002). Thus, the I2 was created to expose future instructors to research-based practices in an experiential setting to effectively change their beliefs about teaching and learning.

Instructional Incubator's Integration of Active Learning

The I2 was specifically designed to model research-based student-centered learning strategies (Maura Borrego, Cutler, Prince, Henderson, & Froyd, 2013) in the classroom for participants. For example, I2 participants interviewed other students and BME stakeholders. Participants were required to observe other faculty at the University and reflect on student engagement. Student learning theory literature was discussed in small groups and as a class. The collaborative jig-saw method (Lom, 2012) was also used as a comparative approach to small group discussion. The course met two times a week. One day was dedicated to active discussion and the other was devoted to in class project-based learning.

Methods

Our study employed a mixed methods approach (Kajfez & Creamer, 2014), using quantitative data to see patterns in perceived gains and qualitative data for insight into participant perceptions of the 30 students who have participated in the incubator course over the first two years (19 in AY17.18 and 11 in AY18.19). An online survey was used to collect data from student participants in the first two years of the I2 (AY17.18 & AY18.19).

Data Collection

A Qualtrics survey was used to collect quantitative and qualitative data at the start and end of the I2. Participants whose data are analyzed in this paper ranged from fourth-year undergraduate students through doctoral candidates in both years of implementation. We asked participants to provide anonymous identifiers of their choosing on pre- and post-course surveys, allowing us to match data across the course, but allowing for anonymity between the participants and the last author researcher, who taught the course. Using this survey strategy, we collected 4 paired survey results for AY17.18 and 10 for AY18.19, giving us response rates of 21% and 91%, respectively. We speculate that the low response rate in AY17.18 can be attributed to students using different anonymous identifiers from pre- to post-course surveys. In the AY17.18 data, students may have forgotten their anonymous identifier, as there were some identifiers in the post-survey that were not consistent with pre-survey identifiers. For AY18.19, we accounted for this by providing participants a list of the anonymous identifiers used in the pre-survey at the beginning of the post-survey.

In the survey, respondents were asked to self-report their teaching abilities by responding to a categorical question about their previous experiences and then rating their perceived effectiveness in those teaching roles in a Likert scale response. They were then asked about their abilities to perform teaching tasks and knowledge of various engineering education terms using Likert scale questions. Respondents were also asked two open-ended questions which asked them to describe learning and effective teaching in engineering.

Data Analysis

Survey responses were analyzed with Microsoft Excel and Qualtrics. Quantitative responses were paired using anonymous identifiers and categorized by academic year (2017-2018 or 2018-2019). For the question on previous experiences, we totaled the number of participants who indicated a given experience and then performed descriptive statistics on the Likert scale responses. To analyze the remaining Likert scale responses (abilities to perform teaching tasks and knowledge of terms), we averaged the responses for pre and post-surveys for data display purposes, separating them by academic year (17.18 or 18.19). We then utilized paired t-tests to determine significant results by academic year.

To analyze the qualitative survey results, we used a deductive coding approach with focused codes (Cho & Lee, 2014) meant to gauge the influence of the I2 on participant beliefs regarding teaching and learning. To do this, we based our codes on learning theories which have been previously described as applicable to engineering education (Newstetter & Svinicki, 2011). We adapted these descriptions to fit the coding purposes of our qualitative data (Table 1).

Table 1: Focused codes for learning theories

Code	Newstetter & Svinicki definition	Adapted definition	What it is	What it is not
Behaviorist	Learning is the creation of stimulus-response connections through exposure, repetition, and consequences.	Learning is a direct response from a mental database of possible responses in reaction to a problem, question, or challenge.	Taking in information or stimuli without processing it.	Interpreting, processing, or analyzing information.
Cognitive	Learning is the process of creating mental models.	Learning is the development of a network of mental models.	Moving information from short term to long term memory by incorporating it with previously established knowledge. Using real world examples to process the content.	Regurgitation of facts, rote memorization, or knowledge owned by a group
Situated	Learning is moving from peripheral forms of participation in a community to full participation facilitated by apprenticeship opportunities to observe and then practice activities.	Learning is the development of an ability to participate or contribute in a community of practice, by developing knowledge or skills used by the community.	Increasing participation or exploring identities in a community of practice. This can be through real world examples or teamwork activities that mimic professional situations.	Independent of context or an activity performed only by an individual.

Then, the first three authors coded the data independently and subsequently discussed until consensus was reached for each response. Achieving consensus consisted of each researcher presenting their reasoning for their selected code, discussion about coding criteria and consistency of applying the criteria across responses, and subsequent selection of the assigned code as a group.

In the open-ended survey questions, responses varied in length and, as such, the researchers coding responses decided together that some responses did not provide enough context to fully understand the respondent's views on teaching or learning (e.g. "Learning is acquiring skills, knowledge, and experiences.") Because these responses were part of an anonymous survey and not collected as interviews, we could not follow up with such responses to get more information. In these cases, we chose to code them as not applicable and remove them from the analysis rather than ascribing a code with too little information.

Results

Quantitative Results on Self-Report Knowledge and Ability Data

Ability. In the pre-survey, participants were asked to describe their previous teaching experiences as well as rate how effective they felt as instructors in those situations. All 14 respondents had at least some form of informal teaching experience. More formal teaching experience varied (e.g. teaching or assisting in an undergraduate or graduate course), but overall, respondents with teaching experience in both implementation years scored themselves as between neutral and very effective on a five point Likert scale (1 = very ineffective 5 = very effective).

We also asked respondents to assess their confidence in performing various teaching tasks using a five point Likert scale (1 = not confident at all and 5 = very confident). Tasks were separated in two groups: instructor centered (Figure 1A) and student centered (Figure 1B).

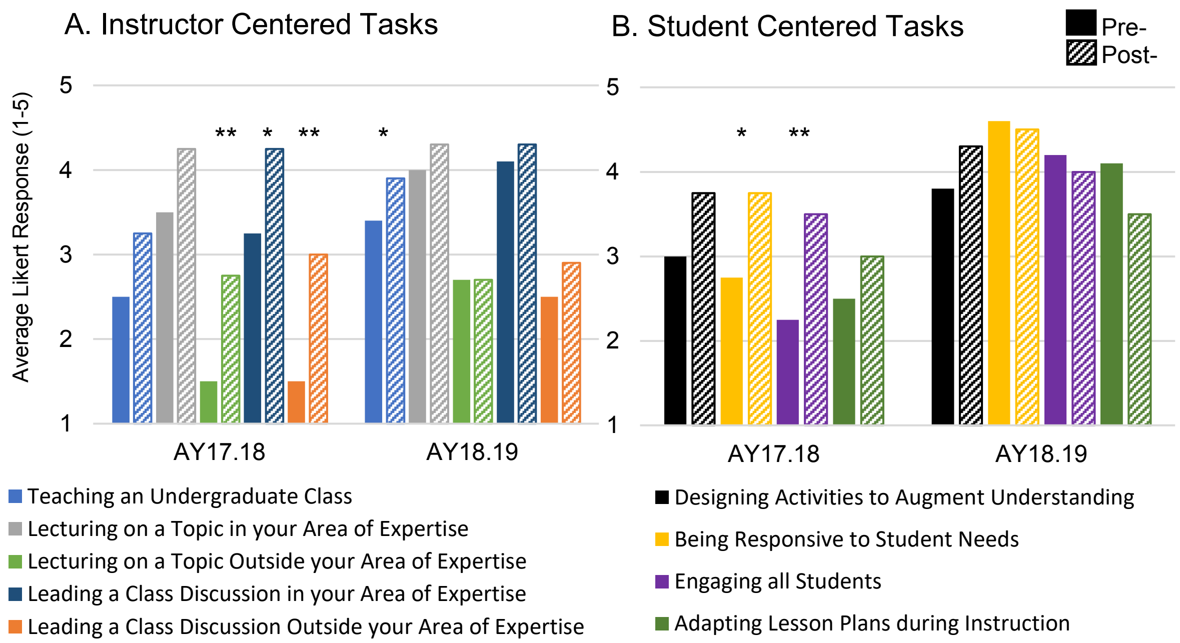

Figure 1: Confidence performing instructor and student centered teaching tasks, *p<0.05, **p<0.01

Instructor centered tasks included: teaching an undergraduate class, leading class discussion (in and outside your expertise area), and lecturing on a topic (in and outside your expertise area). Student centered tasks included: designing activities to augment learning, being responsive to student needs, engaging all students, and adapting lesson plans during instruction. Overall, AY18.19 respondents felt more confident in both types of tasks coming into the course, but paired t-tests indicate that there was limited confidence gained over the time of the course. In the first year (AY17.18), participants expressed fairly low confidence entering the course, but showed significant improvement in confidence in a number of tasks at the end of the course. (Figure 1).

Knowledge. Further, we examined the gains in familiarity with terms related to research and strategies which would signal respondents' ability to pursue additional resources in evidence-based teaching practices. Respondents were asked to rate their familiarity with 10 terms relevant to the I2 course and engineering teaching (1 = very unfamiliar to 5 = very familiar). Before starting the course, both cohorts felt more familiar with terms like: project based learning (PjBL), problem based learning (PBL) [data not displayed], and AL (Figure 2) as indicated by high Likert responses (average above 4 in both years) in the pre-survey. We also examined gains in familiarity with the ten terms, separating them by implementation year. For the sake of brevity, only significant results are displayed in Figure 2. Significant improvement in familiarity which overlaps in both AY17.18 and AY18.19 of the course are AL, learning theories, situated learning, pedagogical content knowledge, and engineering education research. AY17.18 respondents also expressed more familiarity with classroom discourse at the end of the course, while AY18.19 respondents expressed more familiarity with pedagogy.

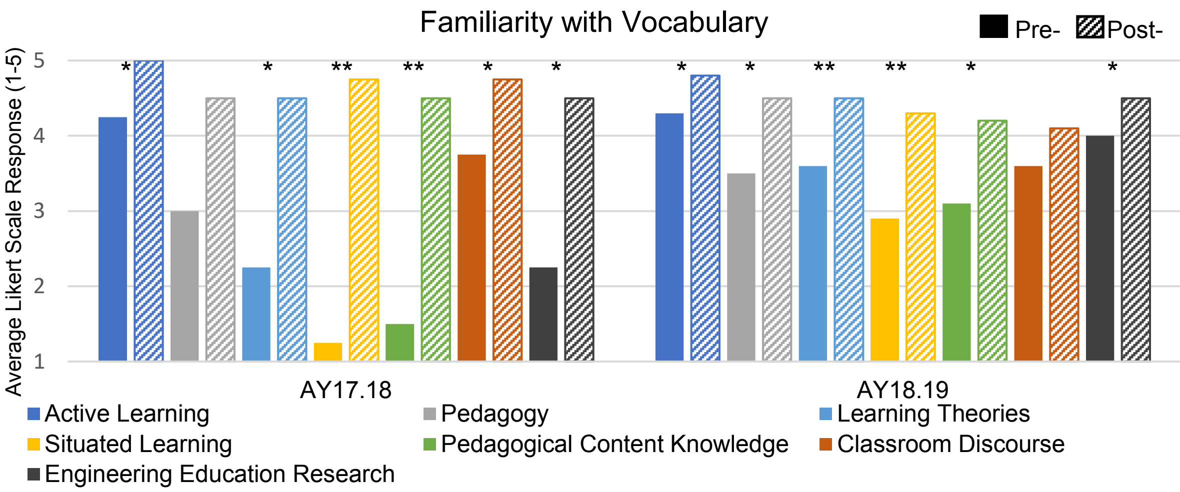

Figure 2: Familiarity with engineering education and related vocabulary, *p<0.05, **p<0.01

Qualitative Results on Participant Beliefs

Beliefs. Beliefs about learning before and after taking the course were probed through two open ended questions about teaching and learning (Table 2). We report the percentage of responses categorized as each theory in Table 2. Results indicate a minor shift in descriptions of both teaching and learning. The number of responses categorized of the 14 total responses is also provided as these affect the percentage reported on the responses placed in each of the learning theory categories.

Discussion

The self-report pre- and post-survey data collected provided insight into how participation in the research-based I2 influences participant perceptions of teaching and learning These results will allow us to iterate on the I2 experience to improve I2 participant learning and make class time more effective. It may also provide insight into aspects of this teaching training strategy which would be useful in improving teaching beyond the institution at which it is implemented currently.

In the first two years, participants enrolled in the course had varying teaching experiences. Many had taught informally or participated in educational outreach. Interestingly, the participants responding in AY17.18 year rated their effectiveness as instructors in the neutral to somewhat effective range of responses while the AY18.19 cohort rated themselves slightly higher. This generally higher self-assessment in the pre-course survey can also be seen in the AY18.19 cohort for questions regarding their ability and knowledge as instructors. This difference in self-rated effectiveness, familiarity with terms, and confidence in teaching tasks may be indicative of participant confidence in themselves as instructors in each cohort, though more investigation is warranted. In the future, we will leverage research on teaching self-efficacy in engineering (Yoon Yoon, Evans, & Strobel, 2014) and pedagogical content knowledge (Fernández-Balboa & Stiehl, 1995) for examining differences in teaching confidence and measurable ability to broaden data beyond self-reports of experience as an indicator of confidence.

Table 3: Participant beliefs in response to questions about perceptions of teaching and learning

Question	Theory	Pre	Post	Example Response
How would you describe effective teaching in engineering?	Cognitive	57%	46%	Effective teaching is enabling/supporting learning as well as the development of mental models in the learners so they can build on them in future.
	Situated	29%	27%	Effective teaching in engineering is teaching that engages students and prepares them to be independent thinkers and doers.
	Bridging Situated and Cognitive	14%	27%	I think effective teaching follows the I do, we do, they do method. Where the instructor shows how the skill or project is done and then the students begin working on it with help and then on their own. I also think hands on work is very valuable for engineers as well as working in groups.
Total Responses Coded		14	11	
How would you describe learning?	Cognitive	84%	64%	Learning is the process by which a person comes to the ability to do, think, process, interpret, or otherwise handle a piece of the world that they could not navigate before learning has occurred.
	Situated	8%	9%	Learning is the accumulation of knowledge through experiences.
	Bridging Cognitive and Situated	0%	27%	Learning is not only being able to understand and identify something that was taught in class, but being able to apply that knowledge for further use following the instruction.
	Behaviorist	8%	0%	Learning is the process of exchanging new knowledge from one person to another. The teacher and the student can learn from each other as well.
Total Responses Coded		13	11	

AY17.18 respondents reported increases in their confidence to lecture outside their area of expertise, lead discussions, be responsive to student needs, and engage all students. These results indicated increased confidence in both instructor and student-centered instructional tasks. AY18.19 respondents rated themselves more confident in all teaching tasks before entering the course than AY17.18 respondents. This higher confidence could be the main reason why we found no significant increases in their confidence in the teaching tasks discussed in the survey, with the exception of the most general task: teaching an undergraduate course. Furthermore, while not statistically significant, students in AY18.19

reported slight decreases in confidence to perform student-centered tasks like: being responsive to student needs, engaging all students, and adapting lesson plans during instruction. It is possible that increased awareness of the many considerations involved in teaching may have negatively affected their outlook on their abilities to perform certain teaching tasks. Future work will use data collected on the same perceived abilities after the Modules, where participants implement their designed courses, to investigate the influence of the mentored teaching experience on confidence levels in the same students.

Unlike the stark difference in ability rating improvement, respondents in both years reported increased knowledge of many engineering education related terms at the end of participation. Further similarities in the data from the two cohorts included high (average above 4) pre-survey ratings of familiarity with terms like AL, PBL, and PjBL. These high ratings could be linked to exposure to these strategies or terms from their own previous experience in engineering classrooms. While the terminology may be familiar to participants because of the push to implement them in engineering classes (Mills & Treagust, 2014), their implementation along with other student-centered strategies are still limited. Further work to investigate the development of participants' conceptions of AL, PBL, and PjBL throughout participation in the I2-Module sequence will offer additional insights.

Further, the courses diverged in familiarity with two terms: classroom discourse (AY17.18 significant) and pedagogy (AY18.19 significant). While it is unclear why respondents in AY17.18 but not AY18.19 felt more familiar with classroom discourse, it should be noted that more examples of evidence-based pedagogy were provided in AY18.19 at the cost of in-depth discussion of classroom discourse. Future work to analyze data collected in the Modules portion of the sequence on participants' use of teaching practices which demonstrate knowledge of these terms could provide additional support of the reported gains in the I2 course.

Finally, we observed a shift in the way participants described both teaching and learning. Highly cognitive or behaviorist responses were lower in the post-survey responses and responses that had aspects of both cognitive and situated learning theories were higher. We attribute the shift in responses partially to increasing comfort with the terminology one might use to describe teaching and learning through the I2 course, as well as their first-hand experience with learning strategies tailored to expand beyond or improve the traditionally cognitive teaching strategies in engineering classrooms (Kim et al., 2019; Newstetter & Svinicki, 2011).

Conclusion

Our study suggests the potential value of the I2 semester for graduate students interested in pursuing careers in academia. Participants indicated perceived increases in knowledge and ability to teach engineering content. Their responses also provided insight on relevant future work to analyze data collected throughout the Module portion of the sequence. Furthermore, beliefs of teaching and learning appear to have shifted and perhaps matured through participation in the course. Finally, this work provides a number of directions for further investigation to improve the experience of participants in this course and future engineering educators wishing to provide similar curricular change support to their departments. Future research on the I2 course will investigate differences in participants' self-reports on ability or knowledge and other established outcomes measures related to those constructs as well as investigating the change in familiarity with pedagogical strategies like PBL and PjBL through I2 participation in a more nuanced, qualitative study.

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