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Exploring Biomedical Engineering Students' Self-Raised Motivations for Engaging in Instructional Design

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Abstract

Current research in the field of engineering education endorses a transition toward active learning pedagogies in the classroom to support greater student learning. In several cases, however, a gap exists between the interdisciplinary research supporting the effectiveness of active learning environments in engineering and actual instructional practice. Today, the engineering instruction is often a shared responsibility between faculty, graduate students and senior undergraduates serving in student teaching roles. Thus, there is a need to better support adopting active learning and to better understand the potential barriers that may inhibit instructors from adopting these new pedagogies. To begin to address these needs, we launched a research-based instructional incubator for biomedical engineering (BME) students, upper level undergraduates, graduate students, postdoctoral fellows and faculty. Given the participants' self-selection into the Incubator and more systemic barriers in the field, we were interested in understanding what motivates students to engage in a course around active learning and educational design in engineering. Further, we sought to better understand the pre-conceptions these students may have about learning, as one potential barrier to translating research to practice. We hypothesized that students may enter the course with a broad interest in improving education given their own experiences, but limited understanding of learning as it relates to evidence-based active learning practices. Using data from a long-form, open-ended survey, we qualitatively analyzed student responses to better understand their motivations for taking the course and their conceptions of learning. We present results on BME students' self-raised motivations for engaging in educational design and how students conceive learning from the analytical lens of current learning theories.

Introduction

As the cost of higher education continues to increase, post-secondary institutions are under pressure to assess student learning and identify best practices to create meaningful educational experiences for their students. Currently, engineering education research supports a transition towards active learning pedagogies in the classroom [1]. These approaches are meant to better engage students in their own learning experience, leading to deeper learning of a subject [1]–[3]. While these pedagogies may be well-supported and well-researched in literature, there continues to exist a gap between the literature and instructional practice in engineering learning environments [3], [4]. Where does this gap come from and why does this gap persist?

Several barriers that contribute to the limited translation of research-based practices into instructional practice have been identified. Some research asserts that current university structures may not effectively support the construction and maintenance of active learning environments [4]. For example, to increase the translation of research-based active learning pedagogies in STEM classrooms, numerous dissemination and training programs have been initiated. These include faculty teaching workshops and the creation of centers for teaching and learning across universities. While teaching and learning centers and teaching workshops have led to an increased awareness of research-based active learning pedagogies [5], their impact on adoption of these practices has been limited [6]. Most of the existing teaching workshops and centers share information about pedagogies and practices, supporting research about their effectiveness, and tips for using them in their classrooms. These workshops disseminate information through lecture, under time constraints, leaving professors and students to process individually. These structures ignore significant research on teaching development, which identifies teaching as a social practice [7]–[10]. Changing instructional practice must come from social participation within a community of practice, in which instructors socially construct best practice together [10], [11]. The disadvantage of disseminating teaching best practices through singular workshops is that they typically do not create and sustain this social community of practice.

It is also important to note that while teaching and learning centers are a resource to faculty and student instructors, participation is not always compulsory. Faculty and students with a predisposition to wanting to improve their teaching are those that typically seek out teaching and learning center resources. Most graduate programs, which are responsible for training future educators, do not formally, consistently, or effectively support students in understanding teaching and learning [2], [12], [13]. Similarly, many post-secondary faculty are never formally taught how to teach, yet are expected to mentor students in all academic matters [14]. As a result, new engineering faculty and students may not be familiar with any sort of classroom practice, let alone the breadth of recent interdisciplinary research exploring and supporting active learning. Without support or experience, faculty and graduate students in teaching roles are more likely to recreate the teaching patterns that they experienced in their instruction [15], [16]. Lortie [9] describes this phenomenon as the *apprenticeship of observation*, noting, "it begins the process of socialization in a particular way…[but] does not, however, lay the basis for informed assessment of teaching technique or encourage the development of analytic orientations towards the work" (p. 67). Thus, without intervention, faculty and students in teaching roles are likely to teach in the manner that they were taught, unquestioningly. This presents another problem when attempting to translate active learning research to classroom practice. In considering these barriers, we are reminded that, "[t]he complexities of educational innovations require a holistic strategy capable of building change in social practices informed by the practical power of theoretical knowledge" [17]. As such, to better address barriers, we need to develop a more complete practical and theoretical understanding of what it means to translate active learning pedagogy to the instruction for faculty and student instructors. The purpose of this paper is to explore the perspective of students in teaching roles as potential adopters of active learning theory.

Learning Theory as an Analytical Lens

To begin to (re)envision what it might mean to support students in teaching roles and faculty with understanding active learning and teaching, a reassessment of the problem space might be necessary. Fundamental questions in the field of engineering education research (EER) ask how can we support students in learning about the ideas, content and practices associated with engineering. Attempts to answer this question has produced significant research under the title of "active learning" [1], [18]–[22]. In discussing "active learning," we are often addressing pedagogical approaches that have been developed to support increased engagement in the learning process [3]. These pedagogies are developed and influenced from the shared, growing understanding of how people learn, as described in theories of learning and learning science [23]. Active learning pedagogies, such as cooperative learning or project-based learning, tend to draw upon social constructivism and situated theories of learning, as well as cognition [3]. In looking across these theories, learning is not just an act of information processing, but an act of sense-making individually and with a group in a particular context [20]. For over forty years, researchers in the fields of learning science and education have asserted that, "…unless teachers engage with the theories underpinning changes in classroom practice the innovation remains merely cosmetic" [17]. Thus, for active learning pedagogies to be adopted meaningfully by educators, it is important for the educators to recognize the underlying theory.

While research on teaching and learning in EER has not ignored learning science as a field, we believe that explicit connections between the advances in the learning science literature and EER research can significantly contribute to the field [20], [24]. Further, different learning theories describe learning in very distinct ways. The perspective through which one views learning can have an effect, or lack of effect, on how learning environments and instruction are designed [24].Given the need to support faculty and graduate students in doing the work of teaching and learning, learning theories can act as an analytical lens through which to explore how students in teaching roles define learning, and to consider how these definitions may contribute to adoption barriers. As such, in this work, we explore how students describe learning, and we do so from the lens of multiple learning theories, further described in Table 2.

Context for Research: The BME Instructional Incubator

While our research can be applied across engineering graduate education, our efforts are to specifically understand the perspectives of BME students. Given the need to create sustainable communities of practice to support engineering teaching and learning, considering and understanding a specific context is important [10], [25], [26]. The BME students involved in this study were of particular interest because of their interest and enrollment in a BME Instructional Incubator course focused on engineering education curriculum development [27]. The Instructional Incubator is a non-required, experiential course that leads a cohort of graduate students, upper level undergraduates, post docs and faculty through the instructional design process. It should be noted that all participants self-selected into this very particular and unique context. The Incubator connects participants to post-graduate opportunities (e.g. industry, research, government) and educational research literature to support them in the co-creation of 1-credit experiential BME-in-Practice courses. This course acknowledges that learning is both social and situated. As such, it is taught so that students construct knowledge with each other, thus increasing their participation in the community of engineering education and effective teaching. Course instruction was designed to model the numerous active pedagogical approaches students read about and discuss throughout the course (e.g. active learning, problem-based learning, collaborative learning etc.).

Methods

For this study, we were specifically interested in exploring how the Instructional Incubator students articulated their motivations for enrolling in the course. Given the nature of the course material, we were also interested in eliciting how BME students describe learning. These interests stem from our belief that by understanding where students are before entering teaching and learning experiences, we can better prepare them for the experience. Given these interests, our work was guided by the following research questions:

1) *What motivates BME students to participate in the Incubator?*

2) What are BME students' conceptions of teaching and learning?

Prior to any instructional interaction, all participants were asked to complete an open-ended survey probing their motivations for enrolling in the incubator experience and their beliefs on teaching and learning. The specific questions asked can be found in Table 1. Student responses were in full sentence, paragraph format.

Table 1. ***Open-ended Survey Questions***

1. In your own words, why did you enroll in the instructional incubator course?
2. What are you hoping to gain from the instructional incubator course?
3. Could you explain how you think this course will be helpful to your current goals or career plans?
4. In your own words, how would you describe effective teaching in engineering?
5. In your own words, how would you describe less effective teaching in engineering?
6. In your own words, how would you describe learning?
7. In your opinion, what role does the teacher play in helping students learn engineering material?
8. In your opinion, what role does the student play in learning engineering material?

We chose to use an *interpretive* qualitative approach, "…seeking deep understanding by interpreting the meaning that interactions, actions and objects have for people" [28] to analyze survey results. In this, we sought to explore and understand better what it might mean to be a BME student interested in teaching and learning. Informed by the traditions of generating and testing assertions in qualitative research [29], we sought this interpretation through descriptive and focused coding of survey data. Survey responses were first descriptively coded, guided by the research question. Throughout the coding process, themes were the unit of analysis. Subsections of text within an individual response were deemed to contain essential thought, and then coded accordingly. This process is in line with utterance coding within verbal qualitative analysis [30]. All coding was performed by two researchers, and the researchers reached 100% consensus after discussion in inter-rater reliability (IRR).

Focused codes were developed [31], [32] to further interpret Incubator participant understandings of teaching and learning. In developing our codes, we asked a more specific question: *How are BME students' articulations of teaching and learning reflecting theories of learning (e.g., behaviorist, constructivist, cognitive, situated, etc.)?* We chose to draw upon Newstetter and Svinicki [33] interpretations of learning theories, specifically, their definitions of behaviorism, cognitivism and situated learning. Their interpretations were chosen because they: 1) discussed learning theory specifically in an engineering education practice context; 2) looked across several theories within this context; and 3) asserted specific connections between a larger theory group and pedagogical approaches subsumed within that understanding of learning (p. 42). While their definitions align with what is discussed above, their specific interpretations of theories, how the role of teacher and student are articulated, and associate pedagogical approaches are described in Table 2. Table 2 was adapted from Table 2.1 from Newstetter & Svinicki (2014, pp. 42-43). This table guided the focused coding. As a final point in analysis, we looked across responses within individual questions and looked at the number of people aligned with a particular code, to create representative visuals of participant responses discussing learning from a particular perspective.

Table 2. ***Focused Codes for Learning Theories***

Code	Definition	Role of Learner	Images of Instruction
Learning as Behaviorist	In the behaviorist framework, "knowing" consists of long chains of stimulus (S)–response (R) pairs that have been associated with past events and their consequences often enough to form a connection	The learner engages in the stimulus-response training and reacts to the stimulus.	Self-paced, mastery-based design. Although many people have the impression that lecture/objective testing is a behaviorist model, lecture lacks the key features of self-pacing, small steps with immediate feedback, mastery at each step.
Learning as Cognitive	All versions of cognitive theory state that "knowing" consists of having mental models that have been created and stored in the learner's long-term memory as a function of interacting with the environment. Learning is the process of creating these frameworks.	The learner processes information and creates an accurate representation of what is presented in instruction…[i]t is often compared to the workings of a computer	Lectures emphasizing structural understanding of content; Demonstrations of skills by model; Guided inquiry such as experiential learning
Learning as Situated	Learning is signaled by changes in how the learner is able to participate more fully and effectively in an already existing community. This learning is helped along by mentoring and apprenticing of newcomers by fuller participants in the community of practice.	The learner moves towards fuller participation within a community of practice, simultaneously developing an identity. Participation is context dependent.	Learning in practice settings (e.g. service learning, apprenticeships, project work in real work settings) or in simulated practice settings. Simulations of authentic problems (e.g. computer-based simulations)

Note: Definitions are adapted from Newstetter & Svinicki [34] interpretation of learning theory

Results

Responses from twenty-two BME graduate students and three upper level undergraduates were analyzed to explore student motivations and understandings of learning. All BME students reported some teaching experience, in either a formal or informal role. In our analysis of the BME student responses, several themes emerged. These emergent themes help us to make meaning of the BME graduate students self-described experiences. These themes also help us begin to answer our two research questions. In what follows, we present two interpretive themes evident from the long-form, open-ended survey response.

Table 3. ***Demographics of Responding Students***

	Gender		
Participant Type	*Female*	*Male*	***Gender Neutral***
Undergraduate	2	1	0
Graduate	11	10	1

BME students enrolled in the Incubator express a desire for educational improvement. Given the uniqueness of the Instructional Incubator, we found it compelling to explore what motivated students to enroll in the course. In being probed to discuss why they decided to join the course (Table 1, Q1), the majority of students articulated a desire to influence and impact engineering education within the department. Of the 25 student respondents, 16 students specifically articulated a motivation to impact positive educational change. The other 9 respondents articulated interests related to career goals within academia, such as learning how to construct a course (Figure 1). Within the desire to impact educational change theme, the BME students described different goals for change. Example responses for each of the goals have been illustrated in Figure 2. Within Figure 2, the bolded statements emphasize where the students determine a need for educational change. Most broadly, students described wanting to impact general engineering instruction. In Response 1, the student frames change needing to happen at a broader level of engineering. This student specifically notes improvement needing to happen in "how we teach engineers," which speaks to a greater conversation about improving engineering pedagogy [3]. Within BME, students described hoping to impact course structures and course content. In Response 2, the student locates change needing to happen at the BME departmental level, specifically around curriculum structure. Thinking about order and timing of courses is in line with conversations around organizational change in engineering education, and addressing larger concerns of climate [34]. In Response 3, the student locates change needed for curriculum

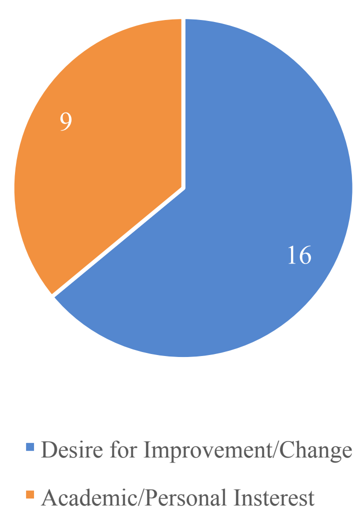

Figure 1. ***Distribution of student motivations for educational change***

content. Specifically, this student notes that definitions of BME need to be better aligned with expected coursework [34]. While each example discusses a desire for change in a different way, all three of these example responses demonstrate aspects of conversations happening broadly in engineering education spaces. In summary, educators and students alike are asking: How do we better support students in learning engineering? The majority of students enrolled in the incubator acknowledges this need for improvement and describe it as their main motivation for participating.

Create Change in General Engineering Pedagogy

Response 1: "I'm interested in learning more about the current 'landscape' of engineering education and **how to improve how we teach engineers**, particularly in the design space"

Create Change in BME Curriculum Structure

Response 2: "I wanted to have the opportunity to utilize my experience of the undergraduate BME program to help develop something that would **further the impact the courses and their timing had on future students**."

Create Change in BME Curriculum Content

Response 3: "I believe that [the Instructional Incubator] will be a very beneficial introduction to a side of academia not often discussed, teaching/course planning. I also am very interested to **observe the ways in which BME curriculum is changing, because I think that there is much work to be done in coalescing what a biomedical engineer is and what they are trained to do**"

Figure 2. ***Sub-goals for types of change within desire for educational improvement theme.***

BME students describe learning in primarily cognitive ways. BME graduate students were also asked how they define the act of learning. Example student responses can be found in Table 3. This table emphasizes how we related each example response to discussion of a particular learning theory, as outline in Table 2 [33]. Bolded text is meant to specifically illustrate the connection between student responses and how a learning theory is defined in research. In this exercise, 24 of the 25 respondents spoke about learning as cognitive (Table 2). This means they were describing learning as an individual processing activity, involving assimilation on knowledge, memory and problem solving. Specifically, the way this group of students described learning related to the information processing perspective of cognition, which states that knowing requires an individual to have mental models which they personally create and subsequently store in their long-term memory after interaction with some sort of environmental cue [24]. The language students used in responses, such as acquiring, processing and assimilating, are also hallmark to descriptions of cognitive theory. Common images of instruction associated with cognitive learning are lectures emphasizing structural understanding of content.

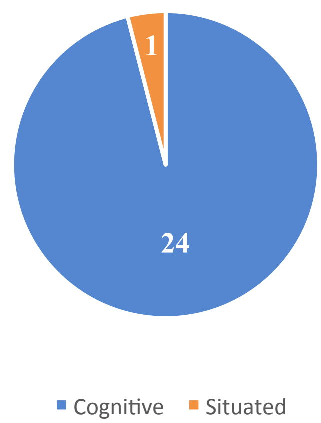

Figure 3. ***Students' responses about learning coded using focused learning theory framework adapted from Newstetter & Svinicki [34].***

Table 3. ***Example Responses for Focused Learning Theory Codes***

Learning Theory Code	Example Participant Response	Description of Theory from Literature [33]
Cognitive	I would describe learning as the **assimilation of knowledge and problem solving.**	"**New information** gets compared to already stored models and is **either assimilated into the existing models**, used to create new models, or modify old ones"
	Learning is the process by which **one acquires the ability to physically or mentally process something** about the world that they were formerly unable to process, whether it be an action, idea, etc.	"The learner **processes information** and creates an accurate representation of what is presented in instruction…[i]t is often compared to the workings of a computer"
	Learning is something that is **unforgettable or easy to remember when it is needed**. Learning is different than memorizing the context for exams. If something is learned, it should come with student after graduation too.	Things that are stored in a structured or richly interconnected manner can be retrieved **to guide behavior when a similar situation is encountered in the future**. Long-term memory is continuously under revision as the **learner is constantly responding to the changing world**"
Situated*	Learning is something everyone does throughout their **entire lives**, ***but it changes***. College is instructional, **where industry is mostly self-taught**. Learning usually **requires mistakes** to be made as well	"[I]n this framework **learning is not generalized** but always constrained by what a community values and adheres to as the members of the community **work through everyday problems**" (p. 38)

Only one student had a response that could be considered participatory or situated [35]. This student stated that learning changes over time and with the environment. This response begins to acknowledge the contextual nature of learning, a hallmark of participatory or situated theories of learning (Table 2). Situated theories of learning posit, "[d]eveloping an identity as a member of a community and becoming knowledgably skillful are part of the same process, with the former motivating, shaping, and giving meaning to the latter…" [11]. This suggests that context, or community, with which the learner is developing identity with matters, and shapes the process of learning. These contexts can be different, from classrooms, to departments, to industry. While we do not claim this response articulated this level of understanding, we did want to separate it from the other responses that do not acknowledge context in learning. The large majority of BME graduate students in this study discussed learning in ways that specifically align with cognitive theory.

Student responses aligning with cognitive theory are consistent with our understanding of EER and traditional engineering experiences. Many students' experiences in engineering reflect learning experiences developed from cognitive perspectives. Lectures, modeled demonstrations, and guided inquiry such as prescriptive laboratory classes align with cognitive theories, that information is individually acquired [24], [35]. We do not claim that students were aware of their theoretical stance on learning. Rather, our finding that the majority of students within our study describe learning cognitively provides insight into another potential barrier to address when translating active learning research to practice in wide scale.

Discussion

As we think about how to holistically address the translation of active learning pedagogies from research to practice, we need to better understand who is doing that work and what problems they may face. Undergraduate and graduate students in instructor roles represent a growing subset of stakeholders tasked with moving educational research evidence into instructional practice. Learning from BME students helps us to better inform how we support them in their professional development and to address the challenge of little experience and mentorship for academic teaching. The finding that the majority of students wanted educational change, and wanted to be involved in making these changes, demonstrates that these students seem open to the work of translation and that there is a resolve for action. The students in this context provide an example of a motivated group of individuals interested in improving engineering education experiences for other students.

Given the significant research on personal and schooling experiences influencing teacher beliefs on education [36], we might expect students who are highly motivated to improve education to think about learning as both social and situated, in ways that align with active learning. For example, a call for better preparation of BME engineers for the work they would be doing in real contexts seems to reflect a view of learning that is social and situated in a BME community of practice [37]. What we see in our data, however, is that these students who express motivations for educational improvement also share beliefs of learning that do not entirely reflect the changes they are calling for, with the majority describing learning as a purely cognitive process. This mismatch might create another barrier for translation of research to practice. Positively, we do not see students describing learning form a behaviorist perspective, a perspective that reflects rote memorization [33]. Yet, more work needs to be done to further push understandings of learning to include situated perspectives, so it is more aligned with the theoretical underpinnings of active learning [3], [20]. We need to better students' conceptions of teaching and learning, so that we can provide support that is better able to challenge and expand singular beliefs of learning as cognitive. Exploring these motivations provides evidence for a need to provide students with more opportunities to engage with their education, through formal instruction and instructional design training.

Findings from this study are also consistent with research findings with respect to apprenticeship of observation. Although motivated, the majority of these students take on stances towards learning that are solely cognitive. Solely cognitive views of learning, without acknowledgement of social context, are contradictory to many active learning pedagogical approaches, such as flipped classroom or cooperative learning [3], [38], [39]. From significant work in learning science and K-12 education, we noted above, "…that unless teachers engage with the theories underpinning changes in classroom practice the innovation remains merely cosmetic" [17]. In other words, trying to adapt pedagogical approaches without understanding the theory that has informed them might make for only superficial changes, not changes that would support deeper learning. Thus, a stance that is unaligned with active learning theory may contribute to a barrier in translating educational research to practice. Given the prevalence of a cognitive stance in our study, we find a need for more transparent integration of active learning theory to practice in instruction and instructional design training. This represents one way to more holistically address the gap between research and instructional practice. Further, more work needs to be done to continue to understand connections between conceptions of learning and teaching practice in an engineering context. Like many other scholars [20], [23], [26], we argue for continued work to connect learning science research with engineering education research, believing these connections will only strengthen our understanding of the barriers to adopting active learning and will support engineering students. In our own work, we hope to continue to explore and make connections between learning science and engineering education in practice [20] for the benefit of all levels of engineering education.

Conclusions

In this study, we explored students in teaching roles as potential adopters of active learning pedagogies. We studied how a group of BME students articulated their motivations for participating in a course on engineering teaching and learning, and how they define teaching and learning for themselves. Learning from their perspectives could help us better understand the challenges of translating evidence to practice. These students were situated in a particular context, having enrolled in the Instructional Incubator, leading them to express motivation for why they want to participate in a greater discussion of teaching and learning in engineering. A majority, 19 of 25 students, expressed a desire to create change in the way engineering is taught. While these results are promising for efforts to improve engineering education, they do not provide insight to the additional hurdles apparent in effectively implementing learning pedagogies in engineering classrooms. In an attempt to further address these hurdles, we used learning theories as an analytical lens to better understand students' current conceptions of learning. When these students discussed learning, the majority discussed it from a primarily cognitive tradition. This stance is consistent with the notion of apprenticeship of observation and the prevalence of lecture-based classes in engineering. Yet, solely cognitive traditions are not always aligned with active learning pedagogies that have been shown to be more effective means of student engagement and learning. Ultimately, we hope this initial analysis of BME students' motivations and beliefs for engineering education can contribute to a greater conversation around how students can play a role in transforming the engineering classroom.

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