Work in Progress: Exploring instructors' decision-making processes on the use of evidence-based instructional practices (EBIPs) in first-year engineering courses

Abstract

Evidence-based instructional practices (EBIPs) are pedagogical practices demonstrated by validated research findings to have a significant impact on student learning. These practices encompass learner-centered learning environments, including guided inquiry, frequent formative feedback, guided notes, and demonstrations, and knowledge-centered learning environments, including problem-based learning, and just-in-time teaching. Over the last twenty years, engineering educators have sought to create engaging learning experiences for students. However, while some educators have had small scale impact on the design of engineering learning systems, previous research have shown that teaching in engineering classes remains largely unchanged. This work in progress (WIP) seeks to highlight how first-year engineering instructors decide what types of instructional practices to use in their classes and how they incorporate these strategies in their course design and content delivery. As part of a much larger study, this paper will explore some of the practices used in first-year engineering courses, how instructors decide on which practices to use based on their experience teaching first-year engineering courses. We will also highlight challenges instructors face in incorporating EBIPs in their classes and share useful strategies they have used to overcome these challenges.

Key words: evidence-based instructional practices, first-year engineering, engaged student learning,

Introduction

Teaching and learning of engineering concepts often demand the use of varied instructional strategies aimed at encouraging students to engage with the material on a deeper level. In keeping with the need to actively engage students while facilitating conceptual understanding, faculty are often encouraged to become creative in their approach to teaching. Numerous studies have been conducted to highlight the necessity of designing learning environments that encourage students to take on active roles in the learning process [1], [2]. To this end, some universities have designed first-year programs tasked with providing students with hands-on activities to foster and promote continued engagement through to degree completion. In colleges of engineering, in particular, first-year programs often employ a project-based structure where students are taught the principles of design and group work using guided inquiry and other inductive teaching methods [3]. However, this is not always the case. In some instances, introductory courses tend to be large and are often focused more on content coverage and introducing students to all engineering specializations rather than providing engaging learning environments.

The classical work of Chickering and Gamson [4] proposed seven principles for good practice in undergraduate education. These principles were: (1) student to faculty interaction, (2) reciprocity and cooperation among students, (3) use of active learning techniques, (4) provision of prompt feedback, (5) emphasis of time on task, (6) communication of high expectations and (7) respect for diverse talents and ways of learning. Since then, some researchers have posited that EBIPs are best suited to engage students and elicit conceptual understanding of complex concepts [5]–[7]. Furthermore, learning environments should support active learning and guide the students towards the acquisition of self-regulated processes. In such a setting, students would be encouraged to construct their own knowledge and skills through actively navigating their role in learning about these concepts. Practices such as interactive engagement through cooperative and collaborative learning, just-in-time teaching, case-based teaching, service learning, peer instruction and concept tests are some of the most common EBIPs used to facilitate student learning and engagement [8].

However, the practices used in classes are typically at the discretion and expertise of the faculty [9]. Therefore, the questions of "What evidence-based instructional practices are currently being used in first-year engineering courses? How do engineering faculty epistemological beliefs about teaching and learning influence what practices they use and their reasons for using particular practices?" remain. This paper documents the beginning of a broader research study that will investigate faculty's use of EBIPs in first-year engineering courses across three Virginia institutions. Further, research activities will focus on faculty's perception of the benefits of EBIPS and barriers to their implementation as well as students' perception of their first-year engineering experience.

Method

Theoretical framework

This work is guided by the pedagogical content knowledge (PCK) framework [10], [11] which is used in research to highlight how the knowledge and beliefs held by educators influence their classroom practices. As instructors design curricula, they tend to blend their own knowledge and experiences about specific content that in turn directly shape how they present material to their students. By using their PCK, instructors also make significant decisions about how learning is best enacted, instructional strategies that facilitate learning as well as what and how concepts are emphasized.

Participants

First-year engineering instructors with varied years of teaching and professional experiences were invited to participate in the study. In this WIP we present the preliminary analysis of data collected from four professors with varied roles and experiences at the same institution. Of particular interest, two of our participants are professors of practice while the other two are tenured/tenure track professors with one being a full professor and the other a junior assistant professor. For the professors of practice, one participant is an associate while the other is an assistant. These participants were intentionally selected because of their similar roles, yet varied levels of experience. The following table summarizes significant details about our participants. Pseudonyms were assigned by the researchers.

Table 1 – summary of participants roles and teaching experience

Pseudonym	Current role	Years of teaching experience (total)	Years of first-year teaching experience
Naomi	Associate Professor of Practice	17	17
Margot	Professor	31	1.5
Hector	Assistant Professor	7	4
Malcolm	Assistant Professor of Practice	4.5	2

Data collection

Data were collected from these four participants using the semi-structured interviews. The interview protocol was designed using the guiding PCK framework. Sample questions from the protocol are provided below:

1. Can you explain what evidence-based instructional practices mean to you?

2. Have you ever used any of these practices in your class?
3. Could you share some of the decisions you make when developing your course materials about what instructional practices you will use?
4. How else do you engage students in the classroom?
5. What do you think is the hardest introductory engineering concept to teach?
6. Could you share your own personal philosophy of teaching?

Preliminary findings and discussions

As mentioned earlier, in this WIP we focus primarily on our participants decision-making processes around what types of instructional practices they use in the courses and how they use them. Additionally, we sought to understand why participants choose to use EBIPs in their course. Some common questions that they discussed always seeking to answer are: *what are my students struggling with? What remains unclear? Is there a better way I can present the material or design learning activities that help them to learn better? How do I communicate my expectations? How can I ensure assessments and day-to-day class activities are aligned with the learning outcomes of that particular class and the course by extension?*

In this section, we share some common themes identified through our preliminary analysis across participants. We also highlight the similarities and differences where they exist among the participants who, as we have previously shown, have varied experiences teaching.

Use of practices that encourage applicability

All four participants discussed how important it is that the instructional practices used in the classroom points to the real-world value of the content. Our participants felt that if students are not made to see how the content they are learning in the classroom applies to something in the real world, then their learning of the content would not be meaningful. Consequently, all four discussed strategies they use in their course design and delivery to ensure students are given the opportunity to explore how what they are currently learning relates to actual practice. For example, Hector had his students engage with a local children's museum to design their project that would be of value to the museum. In this example, the students were taught to see the museum experts as their stakeholders and curtailing their design solutions to not only match the context, but the needs and expectations of their stakeholders as well. This, he felt, was necessary in helping his students understand that what engineers do cannot be void of context or stakeholders.

Use of practices that scaffold learning experiences

The use scaffolding techniques was discussed by all the participants. Scaffolding was determined to be necessary especially in the first-year experience because of its advantage of helping students gain autonomy as they engaged with the course material. Interestingly, Malcolm and Margot, the two participants with the most varied teaching experiences (Margot having the most experience and Malcolm the least) both discussed often feeling challenged when trying to determine what the right amount of scaffolding should be. Margot described their ongoing tension about *"giving students enough structure while encouraging autonomy so that while they not only gain confidence in their learning but that they can be successful"*. Similarly, Malcolm expressed this challenge as *"being aware of students' prior knowledge and experience as using that to determine how much they already know and how much freedom I can give them to explore knowing fully well that if they don't know enough and I hold too high expectations of them I can completely destroy their interest in further technical exploration"*. Overall, all four participants shared always being mindful of their expectations of the students and how they use these to guide the design of classroom activities.

Use of practices that help students develop an appreciation for engineering problem-solving
Developing an appreciation for the open-endedness and ambiguities associated with engineering problem-solving was discussed by all participants as an important outcome of first-year engineering courses. One key skill identified as problematic for students is the importance of algorithmic thinking that is necessary for engineering problem-solving and challenging for students to grasp. The participants all discussed that students' learning experience up to this point has been very regimented, structured and linear. Therefore, creating opportunities that encourage them to change that mindset is often met with resistance. Hector commented *"students often struggle with changing the way they have been trained to think up to this point".* Malcolm described this process as *"getting them to learn how to be comfortable with being uncomfortable. I strive to teach my students to think about the why and not just the how"*. Similarly, Naomi described how she uses reflection activities to help students get over the fear of failing which often comes from prior learning experiences that espouses always having one right answer. Engineering practice, all participants discussed, cannot be explained by a single path to a right answer. Often there is no right answer or a single way to get to a solution and the first-year experience should prepare students for this reality.

Overall, participants agreed that the learning environment should provide a space for the construction of knowledge while guiding students in the development of autonomy over their own learning without causing undue stress and anxiety. Additionally, the choice of EBIPs should encourage the creation of engaging learning environments that build community where students can share ideas, receive frequent formative feedback, interactively participate with each other and be successful.

Conclusions and future steps

Our goal is to continue this work by collecting data from all first-year engineering instructors at three uniquely different state institutions. All first-year engineering faculty at each institution will be invited to participate in the study. Collectively, there are 23 faculty, in addition to the four interviewed in this pilot study, across all three institutions that primarily teach in the first-year engineering programs or introduction to engineering classes all first-year students are required to take. Additionally, at these institutions, graduate students have served as instructors of record. They will be invited to participate in the study as well. We also plan to collect data from the students of these first-year programs using an exploratory survey. The questions on the survey will seek to gather information about students' initial interest in engineering prior to enrolling in their respective institutions, their general perception of the first year courses they have just completed, what their intended majors are, what types of activities they engaged in during their first year course and if/how these activities fueled or increased their desire to continue to pursue their engineering degrees.

References

[1] S. L. Christenson, A. L. Reschly, and C. Wylie, Eds., *Handbook Of Research On Student Engagement*. New York: Springer, 2013.

[2] G. D. Kuh, J. Kinzie, J. H. Schuh, E. J. Whitt, and Associates, *Student Success In College: Creating Conditions That Matter*. San Francisco, CA: Jossey-Bass, 2010.

[3] M. J. Prince and R. M. Felder, “Inductive teaching and learning methods: Definitions, comparisons, and research bases,” *J. Eng. Educ.*, vol. 96, no. 2, pp. 123–138, 2006.

[4] A. W. Chickering and Z. F. Gamson, “Seven principles for good practice in undergraduate education,” *AAHE Bull.*, vol. 1, pp. 3–7, 1987.

[5] R. A. Streveler, S. Brown, G. L. Herman, and D. Montfort, “Conceptual change and misconceptions in engineering education: Curricular, measurement, and theoretically-focused approaches,” *Cambridge Handb. Eng. Educ. Res.*, pp. 83–102, 2014.

[6] C. S. Kalman, “Promoting conceptual change using collaborative groups in quantitative gateway courses,” *Am. J. Phys.*, vol. 67, no. S1, p. S45, 1999.

[7] E. L. Zirbel, “Teaching to promote deep understanding and instigate conceptual change,” *Bull. Am. Astron. Soc.*, vol. 38, p. 1220, 2006.

[8] M. Borrego, S. Cutler, M. Prince, C. Henderson, and J. E. Froyd, “Fidelity of implementation of research-based instructional strategies (RBIS) in engineering science courses,” *J. Eng. Educ.*, vol. 102, no. 3, pp. 394–425, 2013.

[9] W. C. Newstetter and M. Svinicki, “Learning theories for engineering education practice,” in *Cambridge Handbook of Engineering Education Research*, A. Johri and B. M. Olds, Eds. New York: Cambridge University Press, 2014, pp. 29–46.

[10] J. A. Baxter and N. G. Lederman, “Assessment and measurement of pedagogical content knowledge,” *PCK Sci. Educ.*, pp. 147–161, 1999.

[11] H. C. Hill, D. L. Ball, and S. G. Schilling, “Unpacking pedagogical content knowledge : Conceptualizing and measuring teachers’ topic-specific knowledge of students,” *J. Res. Math. Educ.*, vol. 39, no. 4, pp. 372–400, 2008.