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THE REAL WORLD: A FACTOR THAT ENGINEERING FACULTY CONSIDER IN MAKING DECISIONS ABOUT TEACHING

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ABSTRACT

This paper describes a critical decision method (CDM) study for investigating the phenomenon of teaching-related decision-making in engineering education. We interviewed 33 engineering faculty using this method and asked them to identify two memorable, recent teaching-related decisions: one preactive (planning) decision and one interactive (in-class) decision. Faculty described the situation, the process of making the decision, the factors that they took into account, and their level of satisfaction with the outcomes of their teaching-related decision. In this paper, we focus on one specific factor that emerged across the majority of the interviews: the real world. We present ways in which faculty referred to the real world, and more specifically preparing students for professional practice, when making decisions about their teaching. Three themes provided insight regarding the participants' beliefs about this concept; that the real world is hands-on, defineable in terms of professional standards, and that addressing it explicitly in teaching involves trade-offs.

INTRODUCTION

Decision-making is central to the teaching of engineering, however, little has been written about the teaching decisions of engineering educators. We believe that engineering educators can benefit from insights about making teaching decisions because engineering educators are faced with teaching-related decisions on a daily basis. By exploring the processes through which engineering educators make teaching decisions and the factors they consider, we can use decision-making as a means to understand their teaching practices and gain a better understanding of how to help engineering educators make more effective decisions about their teaching. We believe that this approach is particularly appropriate because it is a framework used extensively in engineering (i.e., design decision-making) and thus may be a more familiar framework to discuss teaching practices [1].

We chose to emphasize teaching decision-making using the following educational and psychological definitions. Sutcliffe and Whitfield [2] have defined a teaching decision as "a decision made during the execution of the professional responsibilities of

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the teacher". In addition, teaching decision-making also references the notion of "a decision as a commitment to act. Action is therefore the irrevocable allocation of valuable resources" [3].

The research presented in this paper represents one aspect of a broader qualitative study of how engineering faculty go about making teaching-related decisions. In this larger study, we used a qualitative interview approach using Klein's Critical Decision Method [4] to understand engineering educators' teaching-related decision-making. We focused this analysis on 33 interviews with current engineering faculty in order to identify factors that they considered when making teaching-related decisions. This focused analysis of the collected interview data revealed that engineering educators in our sample reported utilizing a range of factors that they felt impacted the decisions they made about their teaching. These factors included time management for both their students and themselves [1], departmental politics, promotion and tenure, personal research interests, student evaluations, and the need to prepare students for engineering practice, or the real world.

In this paper, we will focus on one specific factor that the majority of the participants mentioned when making decisions about their teaching: the real world. The pervasiveness of references to preparing students for professional practice in the real world in and of itself was not surprising given that the engineering batchelor's degree is widely regarded as professional degree intended to prepare students for professional practice. The desire to incorporate aspects of the real world into teaching also reflects recommedations from the National Academy of Engineering report "The Engineer of 2020" about teaching engineering graduates how to incorporate global and societal issues into their engineering processes [5].

The variety of ways that the faculty in this study considered the factor of the real world and how they decided to incorporate this into their teaching provides specific and useful examples for anybody who teaches engineering. In this analysis, we seek to answer the following two research questions:

1. How did engineering faculty refer to the real world?
2. In what ways did they consider the real world in making decisions about their teaching?

The results of this study will be useful to practicing engineering educators because we describe specific ways in which current faculty address preparing their students for engineering practice post-graduation. In the discussion, we highlight three ways in which educators, working alone or with colleagues, could make use of the results of this study. In addition, we focus on four broader issues and the related future directions raised by the results of this study.

In the next section, we will provide some theoretical background and motivation for this research. In subsequent sections we will describe our research methods, and present findings regarding how faculty refer to the concept of the real world, including examples of the ways in which faculty members consider aspects of the real world in making decisions about their teaching. Finally, we will present implications drawn from our research results in the form of recommendations for considering the real world factor in teaching engineering.

BACKGROUND AND MOTIVATION

A key goal of engineering education is to prepare students to function in the real world of engineering practice. We anticipate that most engineering educators are already preparing their students to become practicing engineers and are encouraged to do so by their peers, departments and institutions.

However, simply knowing about the real world as it relates to engineering practice is not enough to be able to teach students about it effectively. Effective teachers make use of pedagogical content knowledge [6-8], the knowledge about a discipline that is specific to teaching that discipline. Engineering is an applied science with practical applications and the engineering degree is a professional degree intended to prepare students to function as practicing engineers in the workplace. Therefore, an understanding of the pedagogical content knowledge needed to teach engineering students to become practicing engineers must include an understanding of how engineering faculty go about incorporating the real world of engineering practice into their teaching.

So how can we develop an understanding of the pedagogical content knowledge needed to teach engineering students about the real world? Because decision-making is central to the activity of teaching, it provides a useful framework for eliciting information from engineering faculty about the pedagogical content knowledge they have developed for teaching and preparing students for the real world of engineering practice.

The next three sections provide literature reviews of research in (a) engineering education regarding efforts to prepare engineering students for various aspects of engineering practice; (b) the pedagogical content knowledge needed to teach engineering and science effectively; and (c) decision-making as it relates to teaching. This background forms the basis for our research design, experimental methods, results, and discussion.

The Real World in Engineering Education Research

In recent years, engineering education research aimed at helping engineering students prepare for the real world has been especially evident throughout articles published in the Journal of Engineering Education. These articles studied workplace issues specifically [9]; looked at the effect of incorporating engineering entrepreneurship into curricula on students [10 ,11]; and described how the conceptual framework of engineering ethics helped student identify themselves as professionals and increased their awareness of the responsibilities of professional engineers [12, 13].

Jonassen *et al.* conducted a qualitative study to identify the attributes of workplace problems and presented implications for designing engineering curricula and experiences that better prepare students for solving workplace problems [9]. The workplace is the social context within which engineering practice takes place.

Bilen *et al.* [10] and Dabbagh *et al.* [11] focused on engineering entrepreneurship as a way of modelling professional practice for students. Bilen *et al.* described developing a new engineering entrepreneurship minor at The Pennsylvania State University in which a primary goal was to build student's life skills so they can succeed within innovative, product-focused, cross-disciplinary teams [10]. Dabbagh *et al.* found that first-year engineering students who participated in market game in which they formed IT companies competing for a best design had signifiantly improved perceptions of engineering entrepreneurship, specifically professional skills, over students who completed a traditional class project in which they designed and built a land sailer [11]. Both studies found that undergraduate engineering students benefited from course-based experiences that were designed to simulate real world engineering entrepreneurship experiences.

Ethics is another specific aspect of engineering practice. Loui described how a course in engineering ethics helped engineering students identify themselves as professionals [12]. In a related article, Loui showed that viewers of a new engineering ethics video changed their opinions about the most important responsibilities of engineers, and the importance of meeting environmental regulations when working overseas after watching the video [13].

A common thread across all of these papers is that they illustrated educational programs that are promising in contributing to the development of students' engineering skills, knowledge and mindset in order to help them transition successfully into engineering practice. The authors offered key program components and specific methods from their studies to help build and prepare students' engineering skills for the workforce. These program components and specific methods, along with the knowledge of how students respond and learn from them can be described as the pedagogical content knowledge specific to teaching these engineering skills.

Pedagogical Content Knowledge

Shulman [6-8] termed the knowledge about a discipline that is specific to teaching that discipline "pedagogical content knowledge." Bransford *et al.* [14] described ways in which expert teachers in a particular subject area used their pedagogical content knowledge in their teaching. In a more recent study involving large scale curricular reform across an institution in the United States, Major and Palmer [15] found that the 47 faculty in a variety of fields that included English and education in addition to many STEM disciplines used this pedagogical content knowledge of their diciplines as they made decisions about their teaching while "participating in a campus-wide problem-based learning initiative."

Van Driel *et al.* [16] referred to this pedagogical content knowledge as 'craft knowledge' in a similar study of how engineering faculty teaching first year courses at an engineering college in the Netherlands incorporated a large scale curriculum reform designed to increase retention of first year engineering students at their institution. In both of these these studies, recognizing the teacher thinking and beliefs inherent to this pedagogical content knowledge, or craft knowledge, was key in terms of helping faculty developers understand the decisions that faculty made about their teaching.

Decision-making: a Framework for Understanding Teaching

There are many challenges to understanding decision-making because it is a subjective activity, making it difficult to research and study directly. While most engineering educators acknowledge that they make some explicit decisions, most of their decisions are invisible and unspoken. As researchers, we cannot "see" or "witness" a decision, and therefore must infer from observable behavior or participants' self-reported comments that a decision has been made. The study of the decision-making process is also made more difficult by the ephemeral nature of decisions which happen quickly in people's minds. The challenges related to conducting research about making decisions may have contributed to the paucity of studies that examine teacher thinking and teacher decision-making in higher education [1].

Despite these challenges, educational scholars like Shavelson and Stern [17] clearly state the need for this type of research, especially regarding teachers' pedagogical thoughts, judgments, decisions and how these are linked to their behavior. A review of literature based solely on teachers in the K-12 level suggested that any model that is solely behavioral is conceptually incomplete, not accounting for the predictable variations in teachers' behavior arising from differences in their thoughts, judgments, and decisions. Shavelson and Stern also suggest that empirical research linking teachers' intentions to their behavior can provide a sound basis for educating teachers and implementing educational innovations [1].

Although little has been published regarding teaching decisions within the context of science, technology, engineering and mathematics (STEM) education, some qualitative studies about teacher decisions in higher education do exist. In the United Kingdom, Young and Irving [18] interviewed 46 faculty who taught social policy to undergraduates about their teaching approaches and methods. They found that while the majority of the faculty participating in the study spent a significant amount of time thinking about teaching and preparing to teach, they relied primarily on “tacit knowledge based on their experiences as students and couched in terms used by colleagues.” They made little use of specialized or technical language in discussing their teaching and teaching decisions which had implications for their “ability to make explicit and justify decisions relating to professional practice”, which Young and Irving [18] described as “integrity of practice.”

The next section describes our experimental design and research methods for understanding the ways that the engineering faculty in our study used their pedagogical content knowledge to make teaching decisions about how to prepare their students for the real world of engineering practice.

METHODS

This section will first describe the demographics of the engineering faculty who participated in this study. We will then present the theoretical basis for the interview protocol and the process we used to analyze the interview data that we collected.

Faculty Demographics

We interviewed 33 engineering faculty at a major research-oriented university on the west coast of the United States. The semi-structured interviews ranged from 45 to 90 minutes long, and each interview was recorded with the participants’ consent and later transcribed. All names used in this paper are pseudonyms in order to protect the confidentiality of the participants.

The faculty participants came from a variety of different engineering departments including aerospace engineering, chemical engineering, civil engineering, and mechanical engineering. Of the 33 engineering faculty that we interviewed, 12 were full professors with tenure, 7 participants were associate professors with tenure, 7 participants were assistant professors on a tenure-track, and 7 participants were non-tenure track faculty. Four of the participants had high-level administrative roles within the university in addition to their faculty appointments. We deliberately oversampled for women in the study, with 23 male and 10 female faculty participating, or 30.3% female faculty in our sample. The percentage of female engineering faculty nationally was 10.6% in 2005 [19].

Interview Protocol

This current study used the Critical Decision Method (CDM) [4] approach to elicit the specific information regarding processes and factors that the engineering faculty used when making teaching-related decisions. The CDM builds on critical incident techniques [20] by using a set of cognitive probes to determine the basis for situation assessment and decision-making during critical incidents. Klein [4] describes the CDM protocol as:

> “The CDM, like all critical incident techniques, focuses on non routine cases. Incidents that are non routine or difficult are usually the richest source of data about the capabilities of highly skilled personnel . . . In a critical decision interview, questions always refer to a specifically recalled incident. We usually obtain more specific and useful information when we probe concrete and non-routine events than when we ask about general rules and procedures . . . probing in the CDM is not limited to responses that can be objectively anchored and verified. Questions can sometimes require the decision makers to reflect on their own strategies and bases for decisions . . . the probes are designed to obtain information at its most specific and meaningful level . . . thus we ask the decision-maker to select an incident that was challenging and that, in his or her decision-making, might have differed from someone with less experience.” (pp. 465-466)

This approach is especially apt because it can be used to study people at different levels of expertise in a naturalistic setting by relying on interviews to examine recent cases of interest; in our case, it would be teaching-related activities.

The interview protocol was designed to highlight specific cases of critical decision-making on the part of the professor. The interview began by collecting general demographic data from the participants. We then asked faculty to define a teaching decision in their own words and to describe two specific kinds of teaching decisions that they had made recently: (1) a decision that they made during the planning stage of a class, and (2) an interactive decision that they made “on the fly” during an interaction with a student. We then closed the interview by having faculty summarize their process for making decisions about their teaching in general, and the factors that they considered when making these decisions.

Wherever possible, the two interviewers adhered strictly to the critical decision method (CDM) interview protocol outlined by Klein [4]. As per Klein, this protocol was semi-structured but allowed for probing questions in the interest of further knowledge. For example, one participant insisted that he “never made decisions,” that the class was always based on “exploring” questions that the students asked. In such cases, the interviewer used alternate wording to explore the issues of decision-making in the classroom within a framework that was more comfortable for that particular participant.

More generally, the interviewers had considerable difficulties in getting participants to identify a critical incident and maintain their focus on a single critical decision. Many participants found themselves referring to a chain of unrelated decisions in a stream-of-consciousness fashion. Wherever possible the interviewers attempted to redirect the discussion back to the critical decision(s) that the participants had identified.

Data Analysis

For each participant, we identified two teaching decisions to be analyzed using the critical decision method. As noted above, in some cases not all of the transcripts yielded decisions that could clearly be analyzed as critical decisions. All decisions were coded regardless of how well they conformed with the critical decision method approach described by Klein [4].

At a general level, areas for coding were first identified through a series of inductive exploratory exercises. Values were identified inductively through a series of discussions about interim results as the research group gained familiarity with the data. We then proceeded with a deductive analysis of the data relative to these codes. This pattern of inductively generating ideas and coding schemes and then deductively analyzing data relative to this information is consistent with one of the patterns of qualitative research described by Patton [21].

We first examined each participant's background in order to better understand the participant's decision-making process. Second, we identified the two decisions that participants described during the interviews: a planning stage decision, and an interactive decision made "on the fly" during an interaction with a student or students. We extracted these decisions from the interview transcripts for further analysis. We then used thematic analysis to identify multiple themes related to teaching-related decision-making from these interview extracts of specific teaching decisions.

A significant theme that emerged from the data was the need to consider the real world when making decisions about teaching engineering. In general, engineering is a highly applied science and the majority of undergraduates obtaining an bachelor's degree in engineering will work in industry upon graduation. Given this context it is not surprising that faculty articulated the importance of preparing their students for engineering careers in industry, and used the term "real world" as a proxy for these issues.

We then further refined and developed the coding scheme for the real world. In the coding the interview transcripts for the real world, we became interested in answering the following questions:

1. How did engineering faculty refer to the real world?
2. In what ways did they consider the real world in making decisions about their teaching?

We used the following three values when coding the decisions with respect to the real world factor:

Yes-literally mentioned: If at any point during the discussion of the decision, the participant used the phrase "real world", the real world aspect of the decision was coded as "Yes-literally mentioned."

Yes-implied: If, during the discussion of the decision, the participant implied a concern about the potential impact of the decision on the student's professional career, but did not use the words "real world" or any equivalent, the real world aspect of the decision was coded as "Yes-implied."

No: If the participant never made any reference, explicit or implicit, to any professional concerns or any impact outside of the college or academic world, the decision was coded as "No." This code was used as the default if the faculty member's view of the impact of the decision could not be determined.

Some participants did use the phrase "real world" during the course of the interview, but not in the portion of the interview transcript that was identified as a description of the critical decision. In these cases, the "Yes-implied" or "No" coding was used as appropriate for each decision.

The types of analyses that are possible given the type of coding described here include quantitative analyses such as counting the number of occurences of each of the values, thematic analyses of subsets of decisions (e.g. the subset of decisions coded as Yes-Implied), and descriptive analyses that focus more holistically on all of the coded data. Our emphasis in this paper is a descriptive analysis that focused on themes derived from specific examples of teaching-related decisions in which faculty reported considering the real world explicitly (i.e. the Yes-literally mentioned code) or implicitly (i.e. the Yes-implied code).

Each of these teaching decisions was coded separately by 1 of 10 researchers participating in a graduate level research seminar. The research team analyzing this data was a strongly interdisciplinary team that provided a number of perspectives on the data. The 10 researchers came from a variety of backgrounds which included aerospace engineering, computer science, educational psychology, industrial engineering, mechanical engineering, and technical communication. The team included one professor, two staff research scientists, five graduate students, and two undergraduate students. All members of the team had experience teaching in undergraduate level engineering courses, training courses, or high school environments. Several of the graduate students also had extensive professional experience in the fields of software engineering, IT management, and/or technical writing. Five of the researchers had considerable experience with engineering education research. To be consistent with the established standards of qualitative research, before beginning data analysis, each team member disclosed their background and reflected on the biases brought to the data.

The main tool used to address rigor was a constant conversation designed to (a) acknowledge and compensate for the biases of each researcher and (b) to provide accountability for the coding that each researcher performed. A weekly check of the coding and occasional reliability cross-coding and retooling was performed during the analysis process. Everyone was held accountable for the results of the study.

RESULTS

This section will present the answers to the two research questions: (1) how did engineering faculty refer to the real world, and (2) in what ways did they consider the real world in making decisions about their teaching?

Participants were not asked specifically about the "real world" factor, but rather were asked to reflect on how they made planning and interactive teaching related decisions. After participants described each decision, we asked them to list the factors they took into consideration when making the decision. This factor emerged as something to which most of the participants referred implicitly or explicitly during some part of their interviews. Some participants mentioned the term "real world" literally (Yes-literally mentioned code) or described the real world thematically (Yes-implied code) when listing factors that they considered, but other participants did not list any of these factors specifically during the interview.

In the first part of this section, we describe how the engineering faculty in this study referred to the real world. In subsequent parts of this section, we focus on three of the themes that illustrated the ways that the faculty considered the real world in making decisions about their teaching. These three themes emerged from the data for the two "Yes" codes – the "Yes-literally mentioned" and the "Yes-implied" code and are summarized as:

1. hands-on (e.g., senior portfolios/capstones, group projects),
2. professional standards (e.g., ABET), and
3. trade-offs in teaching (e.g. making choices about including material).

Referring to the Real World

Not surprisingly, most participants implied that their role in preparing students for the real world was some form of helping students apply the material learned in their classes to their future careers as practicing engineers. One participant, Harlan, strove to integrate current events into daily teaching. He tried "…to make the class alive to the students, that this is the kind of problem that you might be confronted with in real life."

Few participants made a literal reference to the real world when describing their specific critical decisions; however, several participants discussed the application of material to the real world in other sections of the interview. When discussing their general processes for decision-making, many participants either literally mentioned the specific words "real world" or implied a reference to the "real world."

We found that the teaching decisions involving this factor were more prominent during planning stage decisions, but were still present in interactive decisions. Participants described incorporating aspects of the real world into the examples they used during lectures, the topics that they used when designing lectures, and the topics that they used when designing student assignments or capstone design experiences. By and large, we saw that participants did not define this term explicitly during the interview, perhaps assuming a shared knowledge of the term "real world" with the interviewer.

The next section will describe themes that emerged from the data about ways in which they spoke of the real world. These themes provided insight regarding the participants' beliefs about this concept; that the real world is hands-on, defineable in terms of professional standards, and that addressing it explicitly in teaching involves trade-offs.

Theme 1: Hands-on

A theme that emerged from these two Yes codes was that of the real world as being "hands-on." Participants discussed issues such as the use of hands-on projects but did not explicitly mention the phrase "real world." The discussion about hands-on projects, group projects, senior capstone projects, and the deadlines associated with these projects were all references to the hands-on real world. Participants described these activities in terms of their ability to prepare students for engineering tasks that they might face in professional practice.

Participants who taught capstone courses described the objective of these senior portfolios or senior capstone courses as summarizing what students have learned in their program and providing a real world application of course material. Culminating senior projects allowed students to reflect on undergraduate course work and apply practical engineering skills to a real world project. One participant described soliciting ideas for senior projects from local companies, "…I guess one of the things is our senior design project. These are always company based projects, so I solicit projects from companies in the area …" This participant specifically chose projects of interest to local industry partners.

Nathan, an associate professor, discussed choosing a specific subject for student projects, rather than allowing the students to choose their own topic. He chose the project because of the possibility of incorporating real world experiences for his students through guest lecturers, experts, and researchers. Nathan designed this course to integrate industry and academic research (real world) experiences through class projects. This planning decision was made purposefully and thoughtfully.

> "That they would be more motivated to really dig into the topics, and they were. Because when they did their final projects that day, they did really – you know, really comprehensive, serious job, really did best effort, you know, and I think it's because they – they appreciated the fact that people were actually interested in what they were going to come up with. Because, for example, the hatchery report they did, that was the first time that anybody had even looked at potential nitrogen releases from fish hatcheries, and so the people that were working at the hatcheries were like, well, I'm actually

really curious with what you come up with, you know, just in knowing whether we're like 1 percent of the nitrogen going into *(the canal)* or 15 percent, you know, we want to know ... And so they were able to resolve that question, I think, in a pretty convincing way. So they knew at the same time that these people that were coming to them were like on the other hand waiting ... "
Nathan, Associate Professor

The theme of hands-on was somewhat coupled with the next real world theme that we present, that of using professional standards to describe the real world or specific accreditation criteria, such as ABET, as a proxy for the real world.

Theme 2: Professional Standards

A second theme that emerged from these Yes codes was that of the real world as being described in terms of professional standards, such as ABET. Participants discussed the real world in terms of what their students might expect to experience during professional practice in their discipline. During many instances in the interviews, participants discussed issues in terms of professional standards but did not explicitly mention the phrase "real world."

Several participants discussed using professional standards as an important factor when planning and prioritizing classroom topics. These professional standards helped participants determine what students needed to function in the real world post-graduation and also satisfied accreditation criteria for their departments. Four participants specifically discussed using ABET as an important factor when planning real world applications of course material. A full professor, who we will call Simon, stated that "... we typically cover a variety of topics that are – that are ABET requirements ... " The professional standard was important for participants when making planning decisions about what to teach. Another participant, a full professor who we will call Ed, stated "... in design we want to address a lot of the ABET professional development issues." For Ed, it was important to address ABET standards when planning the design of his courses.

Trent specifically based both his interactive and planning decisions on professional standards. In describing his planning stage decisions, Trent spoke about making sure that the course was up-to-date with current professional standards. He determined his course readings by critically examining the resources that practicing engineers used in the real world.

"These are documents that if one were grappling with this type of situation as a professional, these are the documents you would go to ... And much more practical rather than theoretical, because in my experience, especially in construction, students don't respond very well to theoretical articles, and personally most of the time construction is very, very applied. The more theoretical you get the more useless you get, in a nutshell ... and plus we had – we used three different pieces of software that are state of the art, you know, have been developed at universities or used on actual projects, are used on actual, you know, $250 million projects."
Trent, Assistant Professor

Ed focused on the real world in an interactive decision, when students did not understand the certain aspects of the course content. He used specific engineering software packages to walk through demonstrations in class; he used simulations to further explain:

" ... good enough that the students feel that they had a positive experience, and I feel like I provided them what they need to know to be professionals in this domain ... "
Ed, Full Professor

When talking about a specific teaching decision that he has made in the class, Eugene, a full professor, emphasized the need to "consider the necessity of the real world." In the excerpt shown below, he referred to the real world in terms of familiarizing his students with standard practices used in industry. He incorporated commonly accepted practices in industry in his classroom teaching, such as requiring his students to use numerical methods to analyze complex systems rather than using closed-form analytical solutions to analyze simple systems. He made this decision in order to better prepare his students for professional practice:

"For example, when I'm teaching a class, my clear decision I make is to emphasize numerical computer simulations of heat transfer problems and not emphasize, you know, the analytical approach, okay. Analytical means the exact solution, okay, so instead of, finding the exact solution of the complex heat transfer problem, I would rather find out numerical solution of the complicated problems. The reason is most of heat transfer problem have no exact solution. They cannot use the mathematic equation to describe this solution, just test using computer to test this, to simulate. I believe that is a decision I made ... It's because in the industry, the people in the industry who do the work and study on the research, and the most of the questions has no analytical solution, no effective solution, so there's an only numerical – numerical approach is only approach, and the most convenient approach, okay, to solve the real world problem."
Eugene, Full Professor

Participants described the real world in terms of the hands-on and professional standards themes for all courses, but more frequently when describing their teaching decisions about more advanced courses. The theme presented in the next section describes the trade-offs associated with addressing the first two themes in courses that are less associated with design projects and more heavily associated with covering theoretical content.

Theme 3: Trade-offs in Teaching

We frequently heard that participants recognized the need to incorporate "real world" analogies and examples into their teaching practice as a way to engage and motivate student learning. However, a previous analysis of this data set by Huang *et al.* [1] showed time to be an extremely salient constraint when faculty made decisions about choosing material to cover. The theme of trade-offs represents ways in which time contraints affected participants' decisions about including material related to the real world.

An associate professor we will call Bea suggested something that may resonate with many faculty members who must choose between including real world examples or theoretical content because of time constraints. Bea spoke of including real world examples in the classroom as a "trade-off" because taking time during a class period in order to demonstrate equipment meant that she had less time to present basic concepts and theory. While both approaches have advantages, determining the balance between real world examples and theoretical content was an issue she considered very seriously in her teaching. Ultimately, she wanted students to take away the fundamentals and have a good understanding of how these fundamentals applied to real world examples, but the amount of time she spent on each of these goals in class was dependent on multiple factors in addition to the real world.

> "…any time I try to introduce something with a real world example there's a trade-off, right, because introducing something physical and taking the time to explain – explain the principle or taking the group of students down to see a piece of equipment that's attached to a wall, I mean it takes time, and one can cover, you know, 10 equations in the time that you …So, you know, it's – it's the factor of what can I get across, how important is this principle to everything else that they're going to need to know after. Is it so underpinning that they can't do without it, or is it something that, yeah, I could spend the time doing that, but it's not on the critical path. It's if they don't understand this now it's something that they can pick up later if they need to. So, um, yeah, all those things come into mind, and I'm not sure that they all receive equal weight, but there's certainly – certainly factors in trying to decide should I spend the time on this or – and how much time should I spend on it, and, of course, it's a continuously dynamic process." *Bea, Associate Professor*

The next section will discuss the implications of these results and provide recommendations for how faculty might consider these results in their own teaching.

DISCUSSION AND RECOMMENDATIONS

In this paper, we explored the ways in which engineering educators reported addressing, in their teaching, the general issue of preparing students for the "real world" of engineering practice. In our analysis of educator reports of teaching decisions that they had made, we looked generally for instances of educators alluding to such a concern.

The three themes reported in the previous section represent threads of commonality across those instances. In particular, we talked about two general ways that educators mentioned taking such "real world" issues into account and also one challenge, the issue of trade-offs. Putting these findings in context, it is important to note that this issue was not the only factor that the educators mentioned. Also, the absence of a mention of this issue by an educator was not interpreted as the educator not taking such an issue into account. Against this backdrop, this paper focuses on documenting what taking this issue into account can look like.

The contribution of this work, indeed the expected contribution of our entire study of engineering educator decision making, is, at its core, a better understanding of teaching in engineering education. Looking ahead, this work has implications for engineering educators and those who work with educators, as well as for future research. We discuss each of these below.

For engineering educators and those who support engineering educators, the implications of the findings stem from seeing the findings as a form of pedagogical content knowledge (the knowledge that educators have about specific ways to succeed at teaching discipline-specific topics to particular students). These findings are representative of the pedagogical content knowledge that individual engineering faculty reported using when they made decisions about incorporating the real world of engineering practice into specific aspects of the courses that they teach. Many of the previously published studies described in the in the background section provided insight about the pedagogical content knowledge of teaching engineering and/or the real world within the context of a much larger effort, e.g. developing new courses [11, 12], creating a new engineering entrepreneurship minor [10], or responding to large scale curricular reform [15, 16].

While faculty sometimes make teaching decisions within a larger scale context, our findings are useful because they represent the types of decisions based in pedagogical content knowledge that engineering faculty make on a daily basis when teaching. Further, the findings represent pedagogical content knowledge to be used as inspiration, a point of discussion, and even a launching off point. Specifically, engineering educators could:

1. Use the examples from our results and discussion section as a starting point or counterpoint for your own thinking about ways to include aspects of the real world into your teaching. Our findings highlight ways that other educators have used their consulting experiences, ABET requirements, and industry contacts to include the real world in their teaching.
2. Address this issue through direct conversation with students and/or through pedagogies that involve authentic engineering activity. First, consider eliciting questions and ideas about real world contexts from your students during lecture or lab sections. Beyond simply making the class more student-centered, such direct conversation can result in students who have engineering experience becoming an additional resource for the class by sharing their experiences and knowledge with other students. Further, such conversation could help an educator gain a sense of how well your students understand engineering practice. Second, consider using tested non lecture-based pedagogies such as problem-based learning and case-based learning since they may encourage analytical skills, creativity, ingenuity, professionalism, and leadership in student groups [5].
3. Use the themes and specific examples from our results section as a launching point for broader discussions of ways to address "real world" preparation in teaching within your discipline. Such discussions could be discussions among colleagues about how they have addressed this issue, and could involve asking colleagues about their teaching decisions and what they consider when making these decisions. Such discussions could also involve other individuals on campus (e.g. faculty developers, colleagues in your department, colleagues in other departments) and off campus (e.g. colleagues at other institutions, local industry, government, or non-profit partners) who may have insight about how to include the real world preparation in teaching. Also, such discussions could focus on practices and best practices for thinking through the types of tradeoffs mentioned by the educators in this study, particularly ways of thinking through the trade-offs that keep student learning at the forefront of the effort.

The main ideas and results of this paper also point to at least four more additional directions for further research. First, the results suggest that the general issue of "addressing the real world in engineering teaching" might be a particularly fruitful place for more systematic collection of pedagogical content knowledge. What other ways do educators go about doing this? What specific strategies do they use? What insights do they build on? The discussions suggested above would certainly provide a fruitful place to continue such investigation.

Second, while it was not our goal, it would be valuable to know more about the extent to which engineering educators currently actively consider "preparation for the real world of engineering practice" when they are making decisions about their teaching. In such a context, our results represent a step toward the development of an instrument that could be used to investigate this issue.

Third, the attention this analysis has brought to the perpetually challenging issue of trade-offs between preparing students for the real world and covering content suggests that perhaps this issue should be more systematically investigated. How do educators understand the trade-offs that they are making? If the trade-off is an issue of short term gain (a single class) versus long term activity (the student practicing in engineering and being able to, or not able to, use the material in such a context), then what would permit educators to make such trade-offs knowingly? What sharing of information? What information representations? What decision processes?

Finally, the observation that few educators spent time explaining their understanding of the real world, while not surprising in the context of the experiment, does raise the question of what those educators think are significant features of the real world of engineering practice. Further, the observation raises the question of the current nature of engineering practice and also the way that engineering students understand the nature of engineering practice. Insights into these understandings, and their alignment, may be particularly helpful for future efforts to support engineering education.

CONCLUSIONS AND FUTURE WORK

In this paper, we have discussed the factor of the real world as it relates to the teaching decision-making that engineering faculty do on a regular basis as they teach their classes. Drawing on data from a study of engineering educator decision-making, we discussed how the 33 engineering faculty in our sample referred to the real world and incorporated aspects of the real world into their teaching. The faculty in our study incorporated aspects of the real world into the teaching-related decisions that they reported making while planning and giving lectures, chosing readings and required software, designing labs, developing homework assignments, and creating industry collaborations for senior capstone projects. In each of these examples, we illustrated the way the engineering faculty in our sample incorporated the concept of the real world into their teaching.

Our findings showed that our sample of engineering faculty members echoed the needs described in the National Academy of Engineering report "The Engineer of 2020" which makes strong recommendations for teaching engineering graduates how to incorporate global and society issues into their engineering processes. Specifically, we found that the majority of the engineering faculty in our study made a significant effort to teach students to become "successful engineers in 2020 will, as they always have, recognize the broader contexts that are intertwined in technology and its application in society" [5].

In this paper, we discussed one factor, the real world, that the engineering faculty in our study considered when making decisions about their teaching. However, it was unclear from our data the extent to which the perceptions about engineering professonal practice held by the faculty in our study mirrored the perceptions held by practicing engineers. Many of the faculty in our study reported having less than 5 years of industry experience. Further research regarding how the perceptions of engineering faculty map to the perceptions of engineering students and practicing engineers is beyond the scope of our current data set and remains an area for future work. We are still in the midst of data analysis in order to understand more of engineering educators' teaching decision-making processes.

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