AC 2012-4055: HOW PROBLEM-BASED LEARNING AND TRADITIONAL ENGINEERING DESIGN PEDAGOGIES INFLUENCE THE MOTIVATION OF FIRST-YEAR ENGINEERING STUDENTS

Dr. Holly M. Matusovich, Virginia Tech

Holly Matusovich is an Assistant Professor in the Department of Engineering Education. Matusovich earned her doctoral degree in engineering education at Purdue University. She also has a B.S. in chemical engineering and an M.S. in materials science, with a concentration in metallurgy. Additionally, Matusovich has four years of experience as a consulting engineer and seven years of industrial experience in a variety of technical roles related to metallurgy and quality systems for an aerospace supplier. Matusovich’s research interests include the role of motivation in learning engineering, construction of engineering identities, and faculty development.

Dr. Marie C. Paretti, Virginia Tech

Marie C. Paretti is an Associate Professor of engineering education at Virginia Tech, where she co-directs the Virginia Tech Engineering Communications Center (VTECC). Her research focuses on communication in engineering design, interdisciplinary communication and collaboration, and design education. She was awarded a CAREER grant from NSF to study expert teaching practices in capstone design courses nationwide, and is Co-PI on several NSF grants to explore identity and interdisciplinary collaboration in engineering design.

Dr. Brett D. Jones, Virginia Tech

Brett D. Jones, Ph.D., is an Associate Professor in the Educational Psychology program within the School of Education at Virginia Tech. He received his bachelor’s of architectural engineering degree from the Pennsylvania State University (1992). Subsequently, he worked as a consulting engineer at an engineering firm. He obtained his M.A. (1997) and Ph.D. (1999) in educational psychology from the University of North Carolina, Chapel Hill, and has held faculty positions as an educational psychologist at Duke University, the University of South Florida, St. Petersburg, and Virginia Tech. He has taught 21 different types of courses related to motivation, cognition, and teaching strategies and he received the university-wide Undergraduate Teaching Award at the University of South Florida St. Petersburg (2003-2004). For his research, he received the North Carolina Association for Research in Education’s Distinguished Paper Award (2000) and the Best Paper Award from the American Society for Engineering Education, K-12 Engineering Division (2010). His current research focuses on applying motivation and cognitive theories to instruction. He developed the MUSIC Model of Academic Motivation with the hopes that novice, as well as experienced, instructors would find it useful as a tool for improving their instruction (see http://www.MotivatingStudents.info/).

Mr. Philip R. Brown, Virginia Tech

Philip R. Brown is a graduate student in the Department of Engineering Education at Virginia Tech. He has a B.S. and an M.S. in electrical engineering from Union College and Duke University, respectively. His research interests include motivation, identity, retention, instrument development, mixed methods research approaches, and connecting research to practice. He teaches in the first-year engineering program at Virginia Tech, and is active in curriculum development.
How Problem-Based Learning and Traditional Engineering Design Pedagogies Influence the Motivation of First-Year Engineering Students

Abstract

Problem-based learning (PBL) is a pedagogical practice suggested as a possible way to promote learning outcomes, such as the ABET criteria. PBL is also gaining traction as a possible way to promote student motivation and retention in engineering programs, although research within this regard is still limited. Understanding the relationship between pedagogical practices and student motivation is critical to creating an environment that supports student learning and to attracting and retaining a diverse and qualified future engineering workforce. Toward that end, this study examined the motivational effects of PBL and a more traditional engineering design (TED) course on first-year engineering students. Analyzing interviews collected as part of a larger study, we employed the MUSIC Model of Academic Motivation to address the question: How do two different first-year engineering pedagogies, PBL and TED, affect students’ perceptions of the usefulness of their first-year coursework and of an engineering degree? Although the overall study design employed mixed methods (observations, interviews, and surveys), this analysis examined student interviews at two research sites. Our participants included ten men and nine women from U1 where PBL was used and four men and six women from U2 where TED was used. All participants were first-year engineering students. The findings showed clear differences across the two sites in how students perceived the usefulness of their course towards an engineering degree. Even though there were differences between the two sites that extended beyond the pedagogies used in first-year courses that could influence student motivation, the differences in instructional methods appears to have played a key part in how students experienced their first-year coursework and developed ideas about engineering work.

Introduction and Purpose of the Research

Problem-based learning (PBL) is a pedagogical practice that has been shown to be effective in science and engineering courses for promoting student learning. This approach is also gaining traction as a possible way to promote student motivation and retention in engineering programs, although research within this regard is still limited. Understanding the relationship between pedagogical practices and student motivation is critical not only to attracting and retaining a diverse and qualified future engineering workforce, but also to creating an environment that maximally supports student learning. Because PBL is being increasingly employed in engineering curricula, particularly in design-related courses, it is essential for educators to fully understand the motivational impacts of PBL to ensure that this promising pedagogy is deployed effectively.

Toward that end, this study examines the motivational effects of PBL and a more traditional engineering design (TED) course on first-year engineering students. Analyzing interviews collected as part of a larger study, this paper employs the MUSIC Model of Academic Motivation (eMpowerment, Usefulness, Success, Interest, and Caring) to address the question: How do two different first-year engineering pedagogies, PBL and TED, affect students’ perceptions of usefulness of their first-year coursework and of an engineering degree? The
analysis presented here focuses on the Usefulness component of the MUSIC model because previous research has shown the particular importance of this construct in engineering contexts. Although the importance of making course content useful by relating content to students’ interests and personal goals has been documented (see for a discussion), how to do so, especially within different contexts such as first-year engineering courses, is less understood. The purpose of this study was to examine how PBL and TED affected first-year engineering students’ perceptions of the usefulness of the course content and to provide examples of the ways in which course pedagogy impacted these perceptions of usefulness.

Defining PBL and TED

This project compares student motivation in a course that uses a well-established PBL approach to a course that uses a more traditional approach to teaching design, TED. Therefore, it is important to understand what we mean by PBL and TED.

PBL, as defined in the literature, has specific features. In PBL, students work in teams to collaboratively solve a complex problem under the guidance of a facilitator (often a faculty member). The facilitator does not serve as a traditional instructor but rather guides the students through self-directed learning. The problems are designed to be ill-structured and challenging to the students, as well as relevant to them. The problems must be sufficiently challenging that students cannot solve them with existing knowledge so new knowledge must be generated with the help of the facilitator. To solve the problem, students must gather information, generate hypothesis for possible solutions, identify knowledge gaps, and repeat this process until a solution is reached. Reflection on the solution process is a critical part of the learning process. Importantly, the role of the facilitator is generally well-defined, while problems follow recognizable patterns intentionally constructed to support collaborative self-directed learning.

TED approaches do not have the same structured, singular definition, and therefore, cover a greater variety of pedagogical practices. Following an extensive review, Sheppard and Jenison classified first-year engineering design courses into four categories based on approach (individual or team) and learning outcome (content or process centric). Many of the courses reviewed were “team-process centric,” and thus featured team-based design project experiences which were not domain specific. TED experiences typically address ABET outcomes related to teaming, identifying and formulating engineering problems, designing an engineering system, and communicating effectively. In addition, where the arc followed in PBL approaches focuses on students’ acquisition, synthesis, and application of knowledge in an intentionally collaborative, reflective context, TED approaches typically take their cue from the traditional engineering design process, with an emphasis on defining user needs and project requirements, generating multiple possible solutions, evaluating those solutions to select candidates for analysis, and developing and testing prototypes. That is, whereas PBL is a pedagogical approach developed to facilitate specific kinds of learning, TED more often is invoked as a way to mimic and thus prepare students for professional engineering practice.

It should be noted that, while some of the TED experiences described within this paper may include problem solving activities that could also be found in PBL courses, the nature of how students go about solving the problem is different for TED and PBL. In PBL, a problem is given to students with little guidance as to how they go about solving it, meaning exactly what tools they should use or what actionable steps they should follow. It is up to the students, using
guidance from a facilitator, to determine the way to solving the problem, and then execute that approach. In a TED course, the same problem will often come with an example procedure for how they can solve the problem. Instructor guidance is more hands-on, and students may be actively driven towards one way of solving the problem. For example, students may be asked to follow a specific design process. Elsewhere in TED courses, there are often more traditional lectures, exams, and individual homework assignments that are not typically part of a PBL course.

We recognize that the use of PBL and TED are not the only differences between the two research sites selected for our project, i.e., this is not the type of direct comparison one might find in experimental studies with experimental and control groups. However, it is still meaningful to examine student motivation with these contexts to better understand how PBL and TED function in real-world classroom settings. In the methods section of this paper, we detail the differences between the two sites that could influence student motivation. However, our results do show that the motivational impacts of the pedagogies themselves can be qualitatively explicated from other factors at the research sites.

Framework

The MUSIC Model of Academic Motivation consists of five components that were derived from research and theory as critical to student engagement in academic settings, including: empowerment, usefulness, success, interest, and caring. The name of the model, MUSIC, is an acronym based on the second letter of “eMpowerment” and the first letter of the other four components. The model, based on social cognitive theory, focuses on the psychological needs of the learner and on how social contexts affect their understandings and behaviors. In this section we provide a brief explanation of the full model that is described in Jones.

The empowerment component refers to the amount of perceived control that students have over their learning. Instructors can empower students by supporting their autonomy. The usefulness component involves the extent to which students believe that the coursework is useful to their personal goals. One implication is that instructors need to ensure that students understand the connection between the coursework and their goals. The success component is based on the idea that students need to believe that they can succeed if they put forth the appropriate effort. Instructors can foster students’ success beliefs in a variety of ways, including making the course expectations clear, challenging students at an appropriate level, and providing students with feedback regularly. The interest component includes two theoretically distinct constructs: situational interest, which is akin to curiosity, refers to immediate, short-term enjoyment of instructional activities; and individual interest, which refers to internally activated personal values about a topic. Instructors can create situational interest by designing instruction and coursework that incorporates novelty, social interaction, games, humor, surprising information, and/or that engenders emotions. Instructors can develop students’ individual interest in a topic by providing opportunities for them to become more knowledgeable about the topic and by helping them understand its value. The caring component includes two aspects: academic caring, associated with the degree to which students feel connected and supported in their courses, majors, and educational goals; and personal caring, associated with the degree to which students feel socially and personally connected and supported. To support academic caring, instructors can demonstrate that they care about whether students successfully meet the course
objectives. To support personal caring, instructors can demonstrate that they care about students’ general well-being and welfare.

According to Jones\textsuperscript{16}, the more that instructors can do to address all of the components in a course, the more likely that they will be at successfully motivating all of their students. For the purposes of the present study, we focused on the usefulness component of the model because: (a) this component is not well understood and “deserves more attention” (p. 64)\textsuperscript{28}, and (b) values such as usefulness can be especially important in predicting engineering students’ desires to pursue a career in engineering\textsuperscript{15}. As noted previously, the usefulness component involves the extent to which students believe that coursework (e.g., assignments, activities, and readings) has utility for their short- or long-term goals. This component is important because students’ motivation is affected by their perceptions of the usefulness of what they are learning for their future\textsuperscript{29,30}. As an example, engineering students would believe that coursework was useful if it provided knowledge or skills that were relevant for their future, such as their future as a practicing engineer.

Methods

We used data from a multi-year, mixed-methods examination of the effects that different first-year pedagogies have on student motivation and particularly on the retention of women in first-year engineering programs. The overall study involves interviews, surveys, and observations of students at two large, public universities in the southeastern United States. For the purposes of this study, we refer to them as State University 1 (U1) and State University 2 (U2). Both universities draw from the top percentiles of both in-state and out-of-state students for their engineering programs. The overall project and details for the research settings have been described previously\textsuperscript{13,14}. Important factors relevant to this analysis include the following:

- At U1, first-year students enroll directly in a specific engineering department, whereas at U2, all first-year engineering students enroll in common courses before choosing their major at the end of the first year.
- At U1 we focused on the biomedical engineering (BME) major because they have a well-established PBL-based first-year course. In this course, students work in teams to solve three increasingly complex problems over the semester with the guidance of a faculty facilitator. Performance on the PBL projects is the primary grade for the course.
- At U2 we studied a course that is offered in the second semester of the first year. This required course is intended for all engineering majors other than electrical and computer engineering majors. Design is studied in this course using an approach that could be classified as TED where the students worked in teams over the semester on a single design project and employ tools and processes considered “typical” or “standard” in engineering design. The design project is only a part of the course along with learning software including Inventor and Matlab. Students have regular homework assignments and exams.

Potential impacts of these differences on our study are addressed in the Results and Discussion sections.

We used case study methods\textsuperscript{31-33} as our approach to the qualitative aspects of the study with this analysis focusing specifically on interviews. Interviews are “an essential source of case study
“evidence” (p. 108) according to Yin\textsuperscript{33}, providing crucial insights on the nature of events being studied. They were chosen as the primary data source for this analysis because they can provide deep insight into how the first-year learning environment at each institution was affecting each student.

Participants

Interview participants were selected on a volunteer basis from students who were involved in previous survey and observation segments of the overall study (see\textsuperscript{13} for more study details). Table 1 includes a list of participants by school and gender. Note that the names are pseudonyms to maintain confidentiality and to protect the identities of the participants.

<table>
<thead>
<tr>
<th>U1 Pseudonym</th>
<th>Gender</th>
<th>U2 Pseudonym</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sadie</td>
<td>F</td>
<td>Harmony</td>
<td>F</td>
</tr>
<tr>
<td>Deirdre</td>
<td>F</td>
<td>Heidi</td>
<td>F</td>
</tr>
<tr>
<td>Haley</td>
<td>F</td>
<td>Maya</td>
<td>F</td>
</tr>
<tr>
<td>Dee</td>
<td>F</td>
<td>Nicole</td>
<td>F</td>
</tr>
<tr>
<td>Hayfa</td>
<td>F</td>
<td>Grace</td>
<td>F</td>
</tr>
<tr>
<td>Jane</td>
<td>F</td>
<td>Cathy</td>
<td>F</td>
</tr>
<tr>
<td>Lia</td>
<td>F</td>
<td>Erin</td>
<td>F</td>
</tr>
<tr>
<td>Shreya</td>
<td>F</td>
<td>Alice</td>
<td>F</td>
</tr>
<tr>
<td>Frank</td>
<td>M</td>
<td>Jena</td>
<td>F</td>
</tr>
<tr>
<td>Zavier</td>
<td>M</td>
<td>Valerie</td>
<td>F</td>
</tr>
<tr>
<td>Peter</td>
<td>M</td>
<td>Emma</td>
<td>F</td>
</tr>
<tr>
<td>Simon</td>
<td>M</td>
<td>Elliot</td>
<td>M</td>
</tr>
<tr>
<td>Serge</td>
<td>M</td>
<td>Doug</td>
<td>M</td>
</tr>
<tr>
<td>Alexie</td>
<td>M</td>
<td>Kevin</td>
<td>M</td>
</tr>
<tr>
<td>Morris</td>
<td>M</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trent</td>
<td>M</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dustin</td>
<td>M</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ira</td>
<td>M</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All interview participants in the study were first-year engineering students of typical college age. A total of 19 participants from U1 (11 male, 9 female) and 14 participants from U2 (3 male, 11 female) participated in interviews. Consistent with case study methods\textsuperscript{31-33} this study involved a sufficient sampling of participants to explore a wide range of experiences, expectations, and perspectives on first-year programs.

The female population was intentionally oversampled in order to collect sufficient data on their experiences. The intention was to have 10 women and 10 men from each school. However, insufficient men responded to recruiting efforts at U2 which led to only three men participating at U2. Implications for this disparity are discussed with the findings.
Data Collection and Analysis

All interviews were conducted at the end of the second semester and after completion of introductory first-year engineering courses. The interview protocol was semi-structured, using focused questions to ensure that certain topics were discussed while taking an informal, conversational tone to make questions more relevant to individual cases. Questions were directed towards finding information about the student’s views on their learning experiences in their first-year course and at their university in general. The interview protocol was designed around the theoretical framework for this study, the MUSIC Model of Academic Motivation.

As each of the constructs in the model is complex in itself, a semi-structured approach allowed the interviewer to follow-up and probe deeper based on participants’ responses. The interview questions that were particularly relevant for the present study included:

- Tell me about your experience in [course name]. What do you like best? What do you like worst?
- Do you find this course interesting? Why or Why not?
- Is this course or the content of the course important to you? Why or Why not?
- How does this course fit or fail to fit your perception of what an engineering does?

Interviews were audio recorded, transcribed verbatim and then analyzed. MAXQDA software was used to facilitate the coding process. A combination of a priori and open-coding strategies were used. The apriori codes came from the constructs defined in the MUSIC model: eMpowerment, Usefulness, Success, Interest, and Caring. Open-coding strategies were used to develop sub-categories within each of those broader codes. The analysis for the present study focuses on the “Usefulness” broad code. The literature definition, sub-codes, definitions, and examples are given in Table 2.
Table 2: Codes Related to Usefulness

<table>
<thead>
<tr>
<th>Literature Definition</th>
<th>Sub-Code Definition</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Students understand why the content is useful” to their short- or long-term goals, including being useful to their interests and/or in the real-world (p. 275)</td>
<td>Usefulness of Course</td>
<td>How useful the course content/experience will be to students in the future</td>
</tr>
<tr>
<td></td>
<td>Usefulness of Course Resources</td>
<td>How useful the students found the class resources (lecture, tools that they have access to, or to specific people in the course)</td>
</tr>
<tr>
<td></td>
<td>Desire to Apply Knowledge</td>
<td>How students want to be able to apply their knowledge to problems they will encounter later</td>
</tr>
<tr>
<td></td>
<td>Description of Useful Skills</td>
<td>Identifying what skills students think will be useful to them in the future</td>
</tr>
</tbody>
</table>

We analyzed each case individually before analyzing across the cases. Looking across cases and combining codes, two overarching patterns emerged. In our Results section we present these two patterns rather than discussing outcomes for each of the four coding categories individually.

We enhanced the trustworthiness of this analysis using researcher triangulation. Multiple researchers were involved in the coding and data analysis. Each researcher was trained in how to code the data by coding simultaneously with another researcher. The new researcher then coded separate interviews, but compared their codes with the codes of the experienced researcher. Disagreements were discussed until agreement could be reached. Additionally, codes and the coding process were discussed among the team analyzing the interview data and across teams analyzing observation data and survey data. Multiple perspectives are consistent with case study research and provide insights that can reduce impacts of bias.
Results

Our analysis points to two key findings. First, participants at U1 in the PBL setting have a higher perceived usefulness of the course, which might lead to a higher motivation towards engineering. A higher perceived usefulness is demonstrated not only through affirmative reports of usefulness, but also through participants’ abilities to clearly articulate why and how the course is useful to them. For example, students at U1 talked about learning about communication skills, researching skills, and problem-solving skills and gave specific examples of how these skills would be useful. In contrast, students at U2 were more likely to simply list the skill. Second, our evidence suggests that the perceptions of usefulness are tied directly to the pedagogical approach and not only to the U1/U2 course settings. What we mean is that a higher usefulness might be anticipated at U1 because participants have already chosen a major, the course is offered in their major, and participants can see the direct benefit of the course to their major. However, our data directly reflect the pedagogy, PBL or TED, and not only whether the course is in the participant’s major. Evidence of these key points is presented in the following sections.

Perceived Usefulness at U1: Communication, Researching, and Problem-Solving

When describing the usefulness of the PBL course at U1, students identified that they learned communication, research, and problem-solving skills. Moreover, they gave specific examples of how these skills would be useful to them in the future.

Communication Skills

When students at U1 mentioned learning about communication skills, they typically gave detailed examples comparing what they were doing in class through PBL to a future work setting. For example, when asked about the usefulness of the course one student said:

I guess, learn how to communicate well with the, with the facilitator, with, uh, you know, Dr. Kahn, you know, be able to under-, you know, work at that level with somebody of higher expertise, because I can imagine that once you go into the field, um, uh, you’re definitely gonna be working with people who are more experienced than you or are experts in some specific field that you just need to know SOMETHING about, but you still have to be able to communicate successfully with them. (Peter)

This participant went on to describe a particular example of a BME alumni working with surgical doctors implanting biomedical devices. The doctor was perceived as someone with different expertise than an engineer and the ability to communicate across the boundaries of expertise was perceived as an important skill. This ability was also seen as an extension of what the student is learning in the PBL course.

Research Skills

Participants also described learning about research skills in PBL that would be useful in future professional practice. When asked how the course fit or failed to fit into what they saw a practicing biomedical engineer as doing, one participant at U1 responded

...I feel like it fits into it, because, you’re doing a lot of research and that’s what you’re gonna have to do as a biomedical engineer, you’re gonna have to research, you just can’t
give a solution off the top of your head, you have to look up information, make sure that all points are covered, so that there won’t be any discrepancies later on. So I feel like it fits into what a biomedical engineer is, you have to do research. (Deirdre)

This participant explained what researching meant to her. It is a process of finding, extracting, evaluating, and using information. The student perceived this as part of the work she will be expected to do as a practicing biomedical engineer.

Problem-Solving Skills

Finally, participants reported that problem-solving was a useful skill that they learned in the course with clear descriptions of problem-solving activities. When asked how the course was useful a participant answered:

...just be able to look at a situation or a problem that you don’t know the answer to and the answer isn’t out there anywhere, there’s nobody you can go to and ask for the problem, but being able to break it down into pieces and then, you know, develop a method for how you’re gonna go through, and try and solve the problem. That’s valuable to anybody. (Dustin)

The student describes problem-solving as being able to break the problem down and then develop an approach that will lead to a solution.

Although many students believed that the PBL course at U1 was useful, this was not true of all students. However, even in cases where the participants did not find the course to be useful, they could still articulate, with specificity in relation to job function, why the course was not useful. For example, one student said:

But like, it seems like a lot of [practicing biomedical engineers] do, like, marketing of their products sort of, at least if you don’t go and get higher degrees, you just go to work with your bachelor’s degree that you get. So, I don’t feel like this class really relates to that very much, other than us giving presentations on stuff, but other than that I don’t really feel like – ‘cause we’re not, I don’t feel like we’re, like, trying to convince people that our product’s the best product out there or convince ‘em why they should be using this as much. (Jane)

This participant foresees having a job that involves marketing biomedical devices, knows that such a job requires making arguments about why a particular product is better than another, and does not see the presentations assigned in this course as accomplishing that goal.

Perceived Usefulness at U2: Writing Reports and Learning the Design Process

Students at U2 were generally less complimentary of the TED-related activities in the introductory course in terms of usefulness. In addition to mentioning specific content learned through other aspects of the course (e.g., the software Inventor and Matlab), they talked about writing reports and learning the design process as useful outcomes. Additionally, participants mentioned teamwork, but it was often a one-line statement with no expansion on what teamwork meant to them.
Writing Reports

With regard to writing reports, students indicated that they learned proper formats and content expectations through the design process. For example, one student said:

*It kinda taught us how to set up a technical report and I, I think that’ll be very important, just to, like, be able to set up that correctly, like – and as we got our graded reports back, there was comments about what we should’ve done better, and stuff like that, and I feel like that’s really important in the future, just to get those comments back. Like, even the little stuff.* (Doug)

Other students thought report requirements called for far too much documentation:

*Um, I guess because it all seemed obvious to me. Like, I was like, “well of COURSE we have different ways to accomplish each function, why do we have to write them down?” Like, it just seemed like a lot of documentation for something that I understood without thinking about it too hard.* (Harmony)

In the first case, the student talked about the report as generating an artifact of work with a generic possible purpose in the future. In the second case the student did not see a use for the documentation at all. Students generally did not express an understanding of the purpose of the reports or how they might be useful in future career activities.

Learning the Design Process

The students described learning the design process similarly, i.e., recognizing it as an outcome but often with either generic or of questionable use in the future. For example, students said:

*…learning those different tools, um, the different types of, like, design charts and all, like, learning how to do all of that, that’ll be useful I’m sure.* (Heidi)

*Um, specifically memorizing the steps and what’s in each step, I feel like, was NOT necessary, because I think in the real world, like you’re gonna go through that process, but not specifically in that order, and it’s not gonna be that structured, it’s kinda gonna go more with the flow. I’m assuming, I don’t know.* (Nicole)

In both cases the students think the design tools will be useful someday, but they do not articulate how they anticipate using them or provide any specific examples.

As with U1, there were students who provided exceptions to patterns. Some students were able to articulate benefits from TED:

*Um, I think [the course] fits into what practicing engineers do pretty well, like, from what I’ve, uh, from what limited things I know about mechanical engineers in the field. But, um, like, especially the design process, because you get an objective, and you have to figure out the best way to do it, the most cost effective, then you have to implement all these different, like you brainstorm different solutions and you have to – I don’t know, and like, working in a team dynamic, it’s, it’s pretty much KEY for what engineers do in the field. Like, I know a few people through my church who are engineers, they’ve been...*
engineers for years and years and years and years, and they talk about how working with
different people is, like, key, and the, the group dynamic and the group design process is
really important. (Grace)

This student can see some direct ways that she might use the design process in the future,
although it is also clear that some of her understanding was gained outside of the course through
engineers she knew at church.

Comparison Between U1 and U2: Focus on the Learning Process Versus Focus on the Tools

Our results also show that students’ perceptions of usefulness of first-year courses are tied
directly to the pedagogical approach and not only to the U1/U2 course settings. Although a
higher usefulness might be anticipated at U1 because participants have already chosen a major,
the course is offered in their major, and participants can see the direct benefit of the course to
their major, our data explicate the pedagogy from the research site. This is evident when students
talk about the learning process. For example, one student talked about the PBL learning process
as a whole:

Again, just the, just the way it’s set up gets you, really helps you learn how to work in a
group and just constantly work on a single problem, which you normally don’t do in any
other classes, it’s just, this class, it’s four problems the whole semester and it’s, it’s just
one giant thing that you work on all the time which is, which you will probably be doing
for a job, so it’s a new type of class, almost, entirely. In high school and in some of the
earlier classes in college, you never actually have a, a class like this where you, you go
and you don’t listen to a teacher, you go and work with a teacher, you’re working on the
problem throughout the class, you’re not learning it and being tested. It’s just a different
type of class all together. (Peter)

This student identifies key elements of PBL when describing valuable skills learned. Such
elements include working on projects that are large in scope and require the help of a facilitator
to navigate. The student contrasts this approach with that of learning material to simply pass a
test.

In talking about the learning process, participants in the TED course tended to describe learning
to use tools to complete a design task:

But, um, like I just thought, like, the really specific methods that we used for, like,
brainstorming weren’t – I mean, I don’t really know, ‘cause I obviously haven’t been an
engineer – but it didn’t seem like they would be that formal. Um, so that just seemed kind
of silly. (Kathy)

I think, um, I guess actually part of the design project we had to do a lot of like, specific
charts and this and this, and I know you need a lot of that in a report, but I think some of
the charts – oh, gosh, I think, like, a lot of the charts that we did, I thought were
repetitive, and now I’m like, double, or – now that I’m really thinking about it, maybe you
do use them, but it seemed like in class when we were learning them that it was a lot of
repetitive stuff. Like, you wouldn’t actually, like – the linear responsibility chart, maybe –
maybe, just, like my team didn’t use it very well? And I – like, talking to other teams, I
don’t think anyone really did. I don’t think anyone, like, the timeline was like, “oh this
date we’re gonna do this,” I don’t think that’s how we worked, how pretty much any
group worked. But, I can see how maybe as a real engineer you might use that, I’m not
really sure. At this level, we weren’t really using the tools like they expected us to. (Erin)

These quotes show a focus on learning about tools and the ability to use them. In the first quote, the student does not think the tools were learned in a realistic way. In the second quote, the student talks about learning about tools, but has uncertainty for how they are actually used in professional practice.

In talking about the learning process, the participants at U1 reflected an understanding and appreciation for the activities in which they engaged to solve the problem. The activities they identified were the foundations of PBL as a pedagogy. They took ownership of the learning process and knew how they might apply what they learned in the future. At U2, the students focused on learning to use tools, but they remained uncertain about how such tools might be useful in the future. A summary of findings is shown in Table 3.

Table 3: Summary Comparison

<table>
<thead>
<tr>
<th>Factor</th>
<th>U1</th>
<th>U2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting</td>
<td>State school, first-year students in a single major</td>
<td>State school, first-year students across many majors</td>
</tr>
<tr>
<td>Pedagogical Strategy</td>
<td>PBL</td>
<td>TED</td>
</tr>
<tr>
<td>Useful to Students</td>
<td>Communication, research, problem solving</td>
<td>Writing reports, design process, individual tools</td>
</tr>
<tr>
<td>Pedagogy vs Setting</td>
<td>Students engage in the PBL as a realistic, but not major-specific, practice</td>
<td>Students learn particular tools that they are not certain reflect engineering practice (not major specific)</td>
</tr>
</tbody>
</table>

Discussion

The purpose of this study was to examine how PBL and TED affected first-year engineering students’ perceptions of the usefulness of the course content and to provide examples of the ways in which course pedagogy impacted these perceptions of usefulness. Specifically, we addressed the research question: How do two different first-year engineering pedagogies, PBL and TED, affect students’ perceptions of usefulness of their first-year coursework and of an engineering degree? Recognizing that the use of PBL and TED are not the only differences between the two research sites selected for our project, we presented meaningful outcomes that help researchers and practitioners understand how these pedagogies function. Moreover, our results show that the motivational impacts of the pedagogies themselves can be qualitatively explicated from other factors at the research sites.

In the PBL setting, groups of students are guided through three increasing complex design problems by a faculty facilitator. In the TED setting, students are taught a design cycle and work in teams to complete a single design project over the course of a semester. PBL participants described how they learned communication, research, and problem-solving skills. They talked...
about learning as a process and mentioned key aspects of PBL as part of the learning process. They also articulated, through specific examples, the ways that the skills they learned would be useful to them in the future. In contrast, TED participants mentioned learning about the design cycle and learning how to write reports, but were less able to articulate how these skills would be useful in their professional careers. In addition, they described the learning process as focused on learning to use specific tools (reports, matrices, etc.). They were not often able to describe how being able to write reports or how knowing the design cycle would be helpful in the future, and sometimes indicated that these skills would not be useful.

The differences are particularly noteworthy because both approaches seek to engage students in practices associated with their chosen professions: biomedical engineering at U1 and engineering broadly at U2. However, the pedagogical approach at U1 focused not only the specific skills students were learning through the PBL model, but also on the ways in which the student-student and student-facilitator interactions shaped that learning. The approach at U2, in contrast, heavily emphasized learning through doing; students were given tasks that “real engineers” do, but did not explicitly address the social interactions (student-student or student-facilitator) of the learning environment. Yet these social interactions, though not themselves intuitively or obviously related to usefulness, appear to have a significant effect on students’ ability to perceive that usefulness. These interactions may be particularly crucial at the first-year level, where students are still in the beginning stages of both self and career exploration as they attempt to understand what people in their field “do” and what the field itself means.

Our previous findings have shown that the PBL approach is empowering to students, as one might expect from the nature of the guided facilitation. The results presented here indicate that the approach also helps students value what they are learning because it enables them to see how the skills they are using will be useful to them in the future. They are learning a useful process in a meaningfully designed social context rather than acquiring a set of tools or practicing procedures. PBL is a guided discovery approach where students can take ownership of their learning making the process and outcomes more useful to them.

**Implications for Practice**

Our study has implications for teaching design in first-year engineering programs. Understanding the usefulness of course content is important to students. Particularly in TED settings, instructors could focus on helping students understand how course content will be useful. Importantly, the approach at U1 suggests that this sense of usefulness can emerge more fully when it involves engaging students in discovering the ways course content is useful in the current project and will be useful in the future. Prior analysis of these data has suggested the importance of facilitators as role models, helping students see how engineering work happens, and the results here suggest that role modeling, and PBL-based facilitation broadly, play a critical role in student motivation.

**Limitations**

One limitation of our study is that U2 has disproportionately more men than women. While our intention was to oversample for women, our sample represents a near reversal in the average male/female enrollment ratios. However, we saw no differences in our analysis by gender, and therefore, do not believe this limitation impacted the findings presented herein.
Conclusion and Future Directions

Our study suggests that PBL environments foster beliefs about the usefulness of critical design skills in first-year engineering programs. Because usefulness is a key component of the MUSIC Model of Academic Motivation, our findings provide evidence for the validity of using the model to study students’ motivations within contexts for learning design among first-year engineering students. In the future, researchers could examine the other MUSIC components to determine whether differences exist in for the other components in PBL and TED instruction. Further, it would be interesting to examine whether the motivational effects of experiences in first-year courses extend into the second year and beyond in engineering programs.

Acknowledgements

This paper is based on research supported by the National Science Foundation under Grant No. HRD# 0936704. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

5. LaPlaca, M.C., W.C. Newstetter, and A.P. Yoganathan. Problem-Based Learning in Biomedical Engineering Curricula. in ASEE/IEEE Frontiers in Education. 2001. Reno, NV.
6. McIntyre, C. Problem-Based Learning as Applied to the Construction and Engineering Capstone Course at North Dakota State University. in ASEE/IEEE Frontiers in Education. 2002. Boston, MA.
