AC 2011-539: PROBLEM-BASED LEARNING: A STUDENT PERSPECTIVE ON THE ROLE OF THE FACILITATOR

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Motivating Factors in Problem-Based Learning: A Student Perspective on the Role of the Facilitator

Abstract

Problem-based learning (PBL) is a pedagogical approach that has been identified as promoting learning outcomes consistent with ABET criteria. Although the learning benefits of PBL have been well documented, little is known about the effects of PBL on students' motivation and engagement in learning. As problem-based approaches are becoming more widespread in use across engineering programs and curricula, it is particularly important to understand the impact that such approaches have on students' motivation. As part of a larger mixed methods study, this paper focuses on the critical element of team facilitation. Specifically, we examine how students perceive the role of facilitators and how these perceptions influence student motivation. Grounded in the MUSIC Model of Academic Motivation, we present findings from interviews conducted with first-year engineering students at two different research sites. State U1 participants are engaged in a well-established PBL-based course. State U2 participants are engaged in a course that uses a project-based approach to integrate design projects into the class (termed traditional engineering design, or TED, for this study). We conducted semi-structured interviews with eleven men and eight women from State U1 and three men and eleven women from State U2 at the end of their first year. Audio recordings were transcribed and then analyzed using MAXQDA coding software. We developed codes inductively through the data and based on relevant literature. Our findings demonstrated that participants at both sites viewed the facilitator (PBL) or workshop leader (TED) as the grading authority, although it was most salient for the TED participants from State U2 and for participants in only one of the six PBL groups at State U1. For most participants at State U1, however, the more dominant function of the facilitator was modeling the engineering problem solving process. These State U1 participants also expressed feelings of empowerment and were motivated to put more effort into their coursework through the engagement of faculty in the learning process.

Introduction

Researchers are increasingly seeking to understand undergraduates' experiences in engineering in order to better prepare future graduates and to support retention and career persistence. Although a number of pedagogical approaches have been suggested to meet these objectives, few studies have examined specific pedagogical approaches through the lens of relevant motivational theories to explore effects on students' experiences in and beliefs about engineering. Problem-based learning (PBL) is a pedagogical approach that has been identified as promoting learning outcomes consistent with ABET criteria, though the motivational impacts of this approach are less understood. Because problem-based approaches are expanding from use in traditional capstone design courses to cornerstone design courses and design courses across the curriculum, it is particularly important to understand the impact such approaches have on students' beliefs about engineering and their intended career plans.

To help address this gap, we are conducting a three-year study using motivation theory to better understand *how* two critical elements of the PBL model, team facilitation and project definition, applied to first-year design courses better support retention and persistence for engineering

students. In this paper, we focus on findings associated with facilitation using interview data from the first phase of the study. The overall study employs a mixed methods design (observations, interviews, and questionnaires) in two settings. At State U1, students select a specific engineering department (biomedical for this study) before entering the university and participate in a well-established PBL-based course in their first-year. At State U2, students enter a general engineering program that uses a project-based approach to integrate design projects into the first-year curriculum; we have termed this approach "traditional engineering design" (TED) because it reflects a common pattern for such projects across programs in the U.S. In this paper, we report the outcomes from interviews with PBL team members from U1 and design team members from U2 to address the research question: **How do first-year engineering students in two different types of design approaches (PBL and traditional design) perceive the role of facilitators, and how does this perception influence these students' motivation?**

To address this question we examine how students describe the role of their facilitator for PBL, and correspondingly, their workshop leader in a TED environment. Based on this description, we consider how students' experiences with facilitators impact their motivation in the course. Importantly, the goal of this study is not to provide a direct comparison between the groups, but rather to better understand the ways students perceive faculty roles and how those perceptions correlate to student motivation.

Background

Problem-Based Learning

Problem-Based Learning (PBL), as defined in the literature, emerged first in medical education and is grounded in theories of constructivist learning and cognitive development.[1] In recent years, however, PBL has emerged as a useful approach to engineering and science education (e.g.,[2-12]).

In PBL, students are provided with an ill-structured problem that they work collaboratively to address. Under the guidance of faculty who function as facilitators rather than instructors, teams of students move through the process of structuring the problem by determining relevant facts, generating hypotheses regarding possible solutions, and identifying their knowledge gaps. They engage in self-directed learning to gather and share new knowledge to address those gaps, and re-evaluate the hypotheses in light of their new knowledge. The process typically ends with reflection. Problems are systematically designed to be complex, ill-structured, and reflective of realistic practice. Moreover, they are intentionally framed to advance skills in knowledge acquisition and problem solving and to promote self-directed learning and intrinsic motivation.[1]

The problems are designed such that students cannot independently solve them, either alone or as a team; thus, the facilitator plays a key role in the PBL model. Throughout the process, the facilitator guides the students through developing both problem-solving and collaboration skills.[1] Barrows describes the facilitator-student relationship as follows: "It is an adult–adult relationship with students aimed at growth and independence, not a parent–child relationship so common between teacher and student in traditional teacher-centered learning."[13] Hmelo-Silver and Barrows provide specific strategies for faculty to facilitate PBL environments that include using

metacognitive questioning, pushing for explanation, evaluating hypotheses, and revoicing ideas among team members.[14]

Because facilitation is a time-intensive process it can easily become a constraint in the proper implementation of PBL.[15] Researchers are examining the most effective ways to train facilitators[16] and are even examining alternative ways to provide facilitation, such as web-based systems, designed to support student learning in many of the same ways a PBL facilitator would including question prompts, peer review, expert modeling, and self-reflection.[17] Such systems are not yet easy to create. Moreover, because little is known about the motivation effects of facilitators, researchers cannot yet predict how these web-based systems would affect student engagement in learning.

Although the words and actions of the facilitators have been studied, little research has examined how students experience the facilitator and how the facilitator's enactment of his or her role contributes to student motivation. The time-intensive nature of facilitation makes it even more critical to understand its impact on student motivation. Therefore, we have designed a study that examines the intersection of PBL and student motivation, giving particular attention to the role of the facilitator.

MUSIC Model of Academic Motivation

This research project is grounded in the MUSIC Model of Academic Motivation conceptualized by Jones to provide a practical resource for educators who want to increase students' motivation[18] (see www.MotivatingStudents.info for more information and related research). Drawing on research and theory, this model proposes five key considerations for faculty to consider in designing more engaging learning environments for students. These factors include: eMpowerment, Usefulness, Success, Interest, and Caring (MUSIC). These components, taken together, represent the key features of a learning environment that most effectively supports student development, enhancing not only classroom success, but identification with and persistence in a given field.

The *empowerment* component of the model refers to the amount of perceived control that students have over their learning and is based on research involving theories such as self-determination theory.[19-21] When individuals feel that they are in control of their learning, they have the ability to make choices and are able to manage their interaction with the learning environment. Empowered students generally exhibit higher levels of motivation.

The *usefulness* component specifies that students are more motivated when they understand how course activities relate to their short- or long-term goals. With respect to the *success* component of the model, students must believe that they can succeed if they have the required knowledge and skills and put forth the appropriate effort. Furthermore, students are more motivated when they feel challenged by a task that is not too easy or too hard. Self-perceptions of competence are central to many motivation theories, such as self-concept theory,[22] self-efficacy theory,[23, 24] self-worth theory,[25] goal orientation theory,[26] and expectancy-value theory.[27]

The *interest* component of the MUSIC model is based on research showing that students are more motivated when they are interested in the course activities or content. The *caring* component is derived from research in the areas of belongingness, relatedness, connectedness,

affiliation, involvement, attachment, commitment, bonding, and sense of community. The underlying principle of the caring component is that all humans have a need to establish and sustain caring interpersonal relationships.[21, 28]

The MUSIC Model and the Role of the PBL Facilitator

The MUSIC Model of Academic Motivation provides a framework for investigating student motivation for engagement in learning and retention in engineering which is very consistent with the principles of PBL. Both the nature of PBL problems and the role of the facilitator are closely aligned with the MUSIC model, although we focus on the role of the facilitators in the present study.

First, PBL empowers students by providing an environment where they are facilitated through self-directed learning and problem-solving. A well-designed PBL environment will contribute to students' success-related beliefs because the active learning environment and support of the facilitator will contribute to mastery experiences which in turn contribute to positive success beliefs.[24, 29]

Second, the complex problems in PBL should be designed to place all students on a relatively equal playing field with respect to skills and knowledge, and thus may alleviate task-orientation issues that can disadvantage some students' mastery. Such an approach can help support all students' belief in their potential to succeed in the course, though such beliefs must also be nurtured by the assignment design, the types of team processes employed, and the support of the instructional faculty. As evidence, a study comparing traditional and PBL approaches to teaching macro-economics in high school, found that PBL was more effective (i.e., increased knowledge) with students of lower verbal ability, higher interest and at extremes (high and low) with regard to problem-solving ability.[30]

Finally, PBL environments can contribute to students' sense of interest and caring through the team structure, faculty facilitation, and problems that represent engineering work. Notably, these aspects are particularly important for women. Some research suggests that being an integrated member of a team contributes to creating a sense of belonging for women and that women view teams as a place to form friendships[31] and as a potential support group.[32, 33] Similarly, collaborative or cooperative learning is also an attractive course structure to women.[34] In a study of ethnically diverse women engineering students, Trenor and colleagues found that a sense of belonging was associated with positive learning experiences.[35] Being an integrated member of a team or group can also contribute to retaining women in technical majors.[32] Such studies suggest that both the problem and team environment within PBL need to be structured and facilitated in ways that promote full participation among all team members and facilitators must consistently insure that all voices are represented across the knowledge-sharing and problem-solving phases of the work.

Methods

The overall three-year research study employs a mixed methods design (observations, interviews, and questionnaires) to examine the relationships between student motivation and both PBL facilitation and the PBL project structure. The established PBL structure of State U1

provides the baseline for understanding the potential effects of PBL on motivation; State U2 provides both the control group (TED) and experimental groups (interventions designed to incorporate key elements of PBL) that will be used to test hypotheses generate from the baseline data. The questionnaires, observations, and interviews were designed to understand the experiences of first-year engineering students in first-year design courses. In this paper, we report the outcomes from interviews with PBL team members from U1 and design team members from U2 conducted during Year 1 of the study, which provide the baseline for all subsequent comparisons. In consideration of the MUSIC Model of Academic Motivation, we adopted a case study approach for this analysis such that each interview participant represents a case. There are 18 cases from State U1 and 14 cases from State U2.

Research Context

The participants were enrolled in one of two universities in the southeastern region of the United States. Both universities were public, research-based, technical universities. State U1 had an undergraduate population of 12,563 with 58% enrolled in the College of Engineering and State U2 had an undergraduate population of 22,522 with 25% enrolled in the College of Engineering. Enrollment details are shown in Table 1.

Table 1: Enrollment Data

Enrollment	State U1[a]	State U2[a]
Total	18,878	29,602
Undergraduate	12,563	22,522
College of Engineering Undergraduate	7,284	5,725
College of Engineering Freshman	1,311	1,208
First-year Bio-Medical Engineering	203	n/a
COE undergrad degrees awarded annually	900	1,166

[a] data taken from the universities' institutional research databases, Spring 2010 data sets

State U1 is in an urban setting with a high racial diversity, whereas State U2 is in a rural setting with 77% of the undergraduate population identified as "White/Caucasian." At State U1, students select a specific engineering department (biomedical) before entering the university and participate in a well-established PBL-based course. At State U2, students enter a general engineering program that uses a project-based approach to integrate design projects into the first-year curriculum.

The first year of this three year research study (the basis for this paper) was purely observational, i.e., without intervention. The intent was to observe established and mature PBL and TED programs before delving into the creation of experimental setups. Because the two programs evolved independently, there are several differences present between the two programs that are not related to the PBL or TED setup. These other differences may contribute to observed differences between the programs. However, as noted earlier, the goal of the study is not to provide a direct comparison between the two sites, but rather to understand more fully how specific elements (i.e., faculty role and project structure) of PBL affect student motivation. This paper focuses on identifying student perceptions of faculty roles (especially in the PBL

environment) and exploring the relationships between those perceptions and motivation. The comparison between perceptions in PBL and TED at this phase is useful primarily for helping to delineate the key elements of PBL facilitation most salient to motivation. Thus while the researchers recognize several confounding differences between the two sites, we focus in this paper on identifying perceptions that help explain the role of the facilitator in PBL environments rather than on generalizing about differences between PBL and TED. For more information on the confounding differences between the two programs, see the limitations section.

Participants

In the first year of the study, we collected base-line information about the two research sites. Collected data included: 1) surveys at the beginning and end of the semester of all students enrolled in an introductory engineering course at each university, 2) observations of teams engaged in PBL at State U1 and engaged in TED at State U2, and 3) interviews with members of the observed teams at State U1 and members of both observed and not observed teams at State U2. It is important to note that the interviews were conducted after observations in order that direct questions could be asked about observed activities in many cases.

At State U1, all participants from the observation phase were invited to participate in interviews. Nearly all volunteers were selected with the exception of a few that had conflicts with available interview times. At State U2, we started with a list of survey respondents who indicated they were willing to be interviewed. We then solicited volunteers from the three workshop sections enrolled in the study and gave preference to students who had also been on design teams that participated in the observation phases. All interview participants were compensated with a gift card to his or her campus book store in the amount of $20.

Interview participants included eleven men and eight women from State U1, for a total of 19 cases. Interview participants from State U2 included three men and eleven women, for a total of 14 cases. At both research sites, we intentionally oversampled women. Figure 1 shows general relationships between participants and facilitators. As shown in Figure 1, State U1 participants were drawn from six different PBL teams who worked with five different facilitators (i.e., one facilitator had two teams). State U2 interview participants were drawn from teams that had participated in observations, as well as students from teams that did not participate in observations but that had the same workshop sections and workshop leaders (see Figure 1). Nine of the participants at State U2 came from TED teams that had also been observed. These teams had one of three workshop leaders. The remaining five interview participants at U2 were on design teams that had not been observed. Although the sample at both schools includes predominantly Caucasian participants, African American, Hispanic, and international ethnicities are represented in the sample.

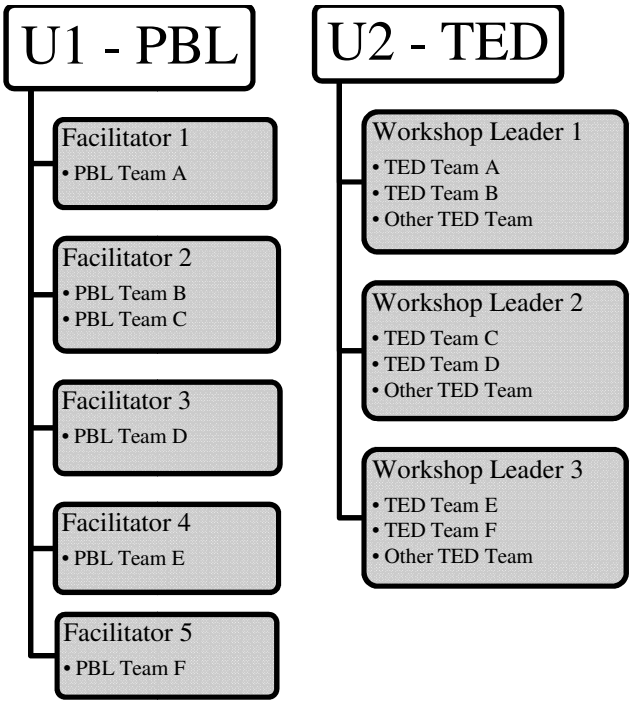

Figure 1: Relationships between student teams and facilitators/workshop leaders

The facilitators at State U1 included two women and three men and included a mixture of post-doctoral researchers and faculty from a variety of educational backgrounds. The workshop leaders at U2 included two women and one man. All three were doctoral students, each pursuing a degree in a different engineering field (engineering education, biological systems engineering and aerospace engineering).

Data Collection and Analysis

Interviews were conducted at the end of the course, which was also the end of the first academic year for participants at each research site. One-on-one interviews lasted approximately 30-60 minutes. The semi-structured interview format included a list of guiding questions, but allowed interviewers the freedom to follow-up on participant's responses as appropriate. Sample questions from the protocol that are salient to this analysis include:

- What do you think are the learning goals in [course name]? (Prompts: Are learning expectations clear? How are they communicated?)
- Do you feel in control of your learning in this class? Why or Why not? (Prompts: What choices are you free to make about your learning? Do you have the right tools to meet the expectations for this course?)
- Do you feel supported in this course? (Prompts: Do you feel like the people in this course support your learning? How?)
- How would you define success in this course?
- How confident are you that you can succeed in this course? (Prompts: Do you feel like you can get a high grade? Do you feel as if you can learn what you are supposed to learn regardless of grade?)

- Describe your interactions with your [group facilitator or workshop leader] in this course. What does he/she do well? What could he/she do differently? (Prompts: How does he/she help you or your team? If you need help outside of class is he/she available?)
- Describe your [PBL or design] team to me. How do the team members interact?

The prompts were used if participants did not understand the questions or if they needed help getting started with an answer.

Audio recordings from the interviews were transcribed verbatim and then analyzed using MAXQDA coding software. We started coding the interviews with broad codes such as "Role of the Facilitator" for any segments of text describing words or actions of the facilitator/workshop leader. We applied the broad codes across all interviews before breaking them down further. With subsequent passes through the data, we developed sub-codes for the role of the facilitator inductively and based on literature suggestions.

Consistent with multiple case study methods,[36, 37] we first coded interviews individually before looking across all interviews for themes and patterns. Cross case analysis included examinations within each research setting and across the research settings.

To ensure the quality of our research, multiple researchers coded the data and we employed interrater reliability checks. A primary coder developed the codes and initial system of application. A second coder was trained in the use of the codes and applied them separately to some of the same interviews. The primary and secondary coder compared results. This process was repeated with clarification and refining of codes until coders could separately code interviews applying the same codes with general consistency. The result of these efforts was a finalized code book. Using this code book, a third coder was trained in the use of the codes and appropriate applications. The third coder independently coded interviews and compared results with the primary coder. Agreement on codes and uses was easily reached after the initial training round. The final codes are listed in Table 2.

Table 2: Codes for Role of the Facilitator/Workshop Leader

Code	Description
Assess Student Performance	assessing student performance formally for the purpose of grades
Building a Supportive Team Environment	working to improve the team dynamics amongst student team members, or the facilitator/workshop leader demonstrating he or she is part of the team, rather than just evaluating it
Structuring, or Breaking Down the Problem	helping the students to break down the problem into manageable parts (e.g., by helping the group delegate different tasks to individual team members, or by setting milestones for the team to fulfill along the way)
Provide Content Instruction When Needed	facilitator/workshop leader providing technical content knowledge (non-design process information) to the students that was helpful in solving the design problem
Model Problem Solving Strategies	facilitator/workshop leader assisting the students by modeling his or her problem solving strategies (e.g., telling the students what they would do to solve the problem explicitly, or by asking probing questions that get the students to think about and explore all the aspects of the problem that the instructor is thinking about)
Engage Students Prior Knowledge	facilitator/workshop leader exploring what the students know and do not know through probing questions that either lead students to an application of current/prior knowledge or reach the limits of the student's prior knowledge

Results

Our findings show clear differences as well as similarities across the two programs that highlight several critical elements of facilitation in PBL environments. Given the very different structures of the programs that we studied at each research site, we anticipated differences, but, as noted, our focus in this paper is on first identifying student perceptions of faculty roles and second, exploring relationships between roles and motivation. Comparing the PBL and TED environments provides valuable insights towards both goals, despite the contextual differences. Moreover, having multiple facilitators at each site is a strength of this study which enables us to also generate insights from the differences we find among facilitators within a site, particularly within the PBL environment.

Assessing Student Performance

Participants at both sites saw the facilitator as the grading authority, although it was most salient for participants from State U2 and for participants in one particular PBL group at State U1. The code for assessing student performance was developed inductively because it was something that many students talked about. However, there were qualitative differences in the way students talked about assessment. For five of the six PBL groups, assessing student performance was mentioned matter-of-factly as something that their facilitator did or even as a positive experience

for students. For example, after describing a situation where the facilitator re-negotiated a grade for her team, Sadie described her State U1 facilitator:

> [our facilitator] understands that this course is very subjective, um, which is difficult at times, because, we could work a lot harder than one group, but if one facilitator doesn't agree with us, either in our paper or our presentation they can just, um, be like, really rude or something like that, so, um, I think just because of all those things, we respect him so much, and really appreciate everything he does to help us out 'cause he wants us to succeed, so we think the world of him, he's awesome.

Sadie saw her facilitator as her advocate when it comes to grades.

In contrast, participants at State U2 and from one particular PBL group at State U1 saw the assessment role as more dominant. These participants were extremely concerned with grades as a measure of performance and ability in engineering and they held facilitators/workshop leaders accountable. For example at State U2, Cathy talks about comparing workshop leaders with her roommate who is also an engineering student but has a different workshop leader:

> And so we were just comparing, like, [her workshop leader] would grade her report totally different than how mine graded mine, and just kind of annoying, 'cause it's like, it's like they aren't, um, I don't know, taking this class as seriously, it seemed like. 'Cause they don't grade fairly, or they don't, um, treat us all equally,

Cathy is bothered by a perceived difference in how grading happens. She sees it as a primary role of the workshop leaders and believes they do not take the responsibility as seriously as they should. Another student at State U2, Jena talked about meeting with her workshop leader to understand exactly what the workshop leader expected for each component of the reports after not doing well on the first several reports:

> …so I had gone in to talk to her about our grade, because I didn't really agree with all of, like, the points she had taken off. Um, so I, like, went in to her office hours to talk to her about that, and then after that I, I like went through point by point for the fourth design report, and said, "okay, what do you want for this? What do you want for this?" And, like, made her tell me specifically what she wanted for each point. And so, we did better after that one and after that I think she kind of realized we actually really trying, maybe, and so I feel like that might've had some effect. Um, and after that, like, I, if I had a question I emailed her and said, "okay, exactly what, like, tell me exactly what you want for this," because I feel like a lot of the points that we were losing was because we didn't maybe do it exactly how she wanted it, and so I started asking her exactly, like, "what do you want? I will do it your way, like, tell me exactly what you want and I'll do it that way." So, we just started, I mean, I was talking to her a lot more just because I wanted to make sure I was doing everything the way I needed to.

Jena saw her workshop leader as a grading authority and Jena's primary goal was to understand exactly what was expected for each section of the design report.

Although the PBL approach more strongly focuses on the learning process and mastery of skills, students in one group at State U1 still had a strong focus on grades and viewed the facilitator as the grading authority. For example, Serge talked repeatedly about grades and his concern over his final grade. When asked if he thought he had all the resources he needed to succeed in the class he said:

> Um, yeah I think I can get whatever resources I need. Like, sometimes I'm very iffy about – like, I have no idea what grade I'm gonna get in this class. And, I just feel like, I don't know if that's just how the class works or if there's any way to improve that. 'Cause we had, like, we had meetings with [our facilitator] – and it's just that, also, different facilitators are different. Like, [our facilitator], she's very harsh on us the whole time, so by the time we get to the end, like now, we're getting good grades, like, we got an A on our paper. But our first paper, we didn't even make a C, and, like, she was just the same level of harshness all the way, so I guess that shows more improvement? But I know, like I have some other friends in different groups, and their, their facilitators are maybe easier, and like they're, they're going on a curve, like, they're grading easier for the first question, harder for the second one, whereas [our facilitator] doesn't do that. [Interviewer: Okay] So it's just kinda confusing, like I have no idea what grade I'm gonna get, and not – I mean, I kinda know how she's gonna calculate it, but not really.

Like many students at State U1, Serge had a GPA-based scholarship and was very concerned about grades and making sure he was meeting the minimum requirement. It was stressful for him not to know what his grade would be in the PBL course. As another example, when asked about the role of the facilitator Alexie said:

> I suppose her job is to put us in the right direction, um, kind of make us learn, once we write an essay – for example, our first paper wasn't that great. However, our second paper, after we took the advice that she gave, things like that, was four letter grades higher. Um, this one was an A, the other one wasn't even a D, I think. But, um, so definitely in that role, I think that she fulfills that role.

Although students in other groups also talked about facilitators pointing them in the right direction, they gave examples related to solving the problem not a grade outcome.

For most participants in TED groups at State U2, a primary role of the workshop leader was as the grading authority. The same was true for one of the six PBL groups at State U1. Participants who viewed the workshop leader or facilitator as the grading authority became frustrated when they perceived facilitators as using invisible, inflexible, or inappropriate grading practices. These participants did not feel empowered in their learning and did not feel confident in their success in the course. They also expressed experiencing less caring from their facilitators/workshop leaders.

Providing Content Knowledge vs. Modeling Problem-Solving Behaviors

Participants at State U1 talked about the main role of the facilitator as someone who is modeling the engineering problem solving process and expressed feelings of empowerment. For example,

when Deidre was asked if she felt in control of her learning (i.e., if she thought she was being told what to do of if she had to figure things out for herself), she said:

> … I would say we're guided to what we're doin' by the facilitators. They won't tell us the answer but they'll guide us 'cause that's what they're there for, they're there to guide us, and to, you know, help answer questions if we need to give them – it'll give us like a sense of them, as a biomedical engineer already, how THEY would digest the problem, and how THEY would do it. And then we have to turn it around, and pretty much WE have control after that.

Specifically Deidre said that they were guided in their learning and that the facilitators modeled how a biomedical engineer would solve the problem. While she also discussed the facilitator as having roles in assessing student performance, building a supportive team environment, and engaging the students' prior knowledge, these roles were secondary to the modeling role.

Also at State U1, Dustin talked about the role of the facilitator as modeling problem-solving. In this case, he was looking for more of that behavior than he was receiving:

> …we understand that the objective of the course is, again, to make sure you can figure this out on your own, essentially. Um, 'cause that's realistic, that's real-life. But, it would be good to have a little more, like, feedback in the form of questions, and having her ask the right questions to point us in the right directions, and I think, um, she's kind of getting better at that, but still it's important for her to know what the right questions are, because sometimes she'll ask a question and we've covered that, and it just had been a while, and that's kind of just a bump in the road, but other times it's a question that's like, "wow, that's an extremely good point," and it kinda shifts us. So more of those questions that are less interruptions and more just reminders to stay to the problem, stay focused, and um, make sure you're accomplishing what you set out to do.

Although the facilitator is seen as asking questions and not giving content knowledge, Dustin would have liked more questions from his facilitator that would have guided him towards a solution as opposed to questions he sees as irrelevant. Noticeably, Dustin did not expect his facilitator to provide content knowledge or simply give the answers; Dustin was looking for more guidance through questioning that would help him succeed or empower him in solving the problem.

In contrast, many State U2 participants talked about their workshop leaders as having the role of providing content knowledge, yet they would have liked some modeling of problem-solving behaviors. For example, in talking about how he interacted with his workshop leader, Doug said:

> I corresponded with [my workshop leader] over email if I had any issues outside of class, and I feel comfortable enough talking to her, like, before or after class if I have any specific questions and always, she's always open to questions in class, so I feel like she's pretty supportive of us and willing to answer questions if we need her help.

Whereas State U1 participants talked about asking questions as a primary role of the facilitator, either in terms of a behavior they experience currently or would like more of, Doug talked about

his workshop leader as having a responsibility to answer questions that the students in the class may ask. Similarly, Valerie saw her workshop leader as giving individual help and answers but would have liked more general guidance for the class:

> I don't know if this applies to just [our workshop leader], but he gives us a lot of time to work on the, the hands on, the programming things, and then, so he just gives us a lot of time and then he'll go around and answer questions which just takes a long time, so it would be better to have more interaction with the students with problems they've had, so you can prevent it for other students, instead of individually going around and asking how your program works

Although Doug felt empowered (in the sense that his workshop leader will answer whatever questions he asks), Valerie desired and would have been empowered by more general interactions and guidance on how to solve problems rather than waiting on individual help.

Participants at State U1 talked about the main role of the facilitator as someone who is modeling the engineering problem solving process and expressed feelings of empowerment. Even though some participants at State U2 described feelings of empowerment, they do not use positive phrases to describe a self-directed learning process like State U1 participants.

Facilitator/Workshop Leader Engagement

Having an engaged facilitator also motivates some State U1 participants to put more effort into their coursework. Several participants recognized the time and effort expended by faculty and, out of respect for them, did not want to waste their time. For example, when asked if the team dynamic changes when the facilitator was not there, Franks said that it did:

> …Because with [our facilitator], we almost feel like we gotta make use of his time, we gotta be very good at using the time with him wisely, because we don't have him all the time. So, we have to come with questions prepared, with research prepared, and just kind of discuss the problem, you know, get down to the hard work, uh, because he's definitely the expert when it comes to a lot of these problems and how to just approach them in general.

Conversely at State U2, workshops were called "boring" and although there was an exception, more enthusiasm from workshop leaders was desired by participants.

Limitations

The data presented here are based observational data collected from two mature first year design programs that have developed through multiple cycles of assessment and continuous improvement. As noted earlier, a direct comparison between the two groups is limited by differences in class setups (PBL versus TED) as well as other confounding factors. However, because this research focuses on understanding the effects of the PBL environment on motivation, the comparison between programs is useful for highlighting both critical features in PBL facilitation and the relationships between those features and student motivation.

To contexualize this comparison, we note several confounding differences between the two programs beyond the overarching pedagogical structure:

First, the facilitators at State U1 included a mixture of post-docs and faculty, whereas the facilitators at U2 were doctoral students. Facilitators at both institutions had differing amounts of teaching experience, ranging from less than a year's worth of teaching experience, to many years' worth of teaching experience. This factor certainly played a role in the class experience for students, but a range of teaching experience at both institutions should help lessen the bias.

Second, the gender ratios for the PBL and TED differ slightly. This was true for both the study population, where State U1 had a higher ratio of women to men, and for the interview participants, where State U2 had a higher ratio of women to men. However, in this analysis, we saw no differences based on participant gender.

Finally, other confounding differences included the number of times the class met per week and majors of the students enrolled in the course. All confounding differences could not be eliminated from the study, as with any observational study, but the qualitative analysis is a tool that is meant to identify trends in contextualized data.

Discussion

Our research question had two parts: (1) How do first-year engineering students in two different types of design approaches (PBL and traditional design) perceive the role of facilitators? and (2) How does this perception influence these students' motivation? The discussion of our results is organized around these two questions.

Perceptions of Facilitator/Workshop Leaders

Our results document that students perceive their facilitators/workshop leaders in the following ways.

- Participants at both sites viewed the facilitator as the grading authority; however, it was most salient for participants from State U2 and for participants in one particular PBL group at State U1. Participants in these groups were extremely concerned with grades as a measure of performance and ability in engineering and they held facilitators/workshop leaders responsible for their grades.
- Participants at State U1 talked about the main role of the facilitator as someone who is modeling the engineering problem solving process and expressed feelings of empowerment. In contrast, many State U2 participants talked about their workshop leaders as having the role of providing content knowledge; but instead, they would have preferred some modeling of problem-solving behaviors.
- Some participants at State U1 were motivated by faculty engagement to put more effort into their coursework. Conversely at State U2, workshops were called "boring" and although there was an exception, more enthusiasm from workshop leaders was desired by participants.

These results are significant for several reasons. First, they show that students experience PBL trained facilitators differently than they experience traditional workshop leaders. Moreover, many students experience PBL in a manner that is consistent with the way that PBL is described in the literature[1]; that is, student perceptions match the intended goals. Facilitators guide students through developing both problem-solving and collaboration skills using strategies such as metacognitive questioning, pushing for explanation, evaluating hypotheses, and revoicing ideas among team members.[14] PBL participants in the present study described several of these strategies in talking about the questioning approaches of their facilitators. Conversely, students experienced TED projects as more instructor-focused than student-centered, which is not consistent with the goals of this approach. The finding is particularly significant given the emphasis on projects in engineering courses because it suggests that the inclusion of projects alone may not be sufficient to effectively support student engagement. An intentional PBL framework includes not only open-ended problems, but a way of structuring interactions both within teams and between teams and the facilitator that may affect engagement for first-year students.

Second we found that it is not just the PBL structure of having a facilitator, but rather the way that facilitators enact their role that is important. This is shown explicitly through the one PBL group whose students focused on grades. Because they perceived that the facilitator was grading them extra harshly, the participants felt stressed and uncertain about their grades. The focus on grades took precedence despite the PBL approach having a strong focus on the learning process and mastery of skills.

Perceptions of Facilitators as Related to Student Motivation

PBL did indeed empower students by providing an environment where they were facilitated through self-directed learning and problem-solving. Participants at State U1 talked about the primary role of facilitators as modeling problem-solving behaviors which enabled the PBL teams to work towards meaningful problem solutions. In comparison, TED groups were less empowered and looked to their workshop leaders to provide answers. Moreover, unlike the State U1 PBL participants, no participants at State U2 describe the TED learning process with positive phrases that describe a self-directed learning process.

By shifting the focus from grades to the learning process and mastery of skills, in all but one case, PBL promoted success beliefs. Participants in five of the six PBL groups talked positively about working towards problem solutions and only one PBL group expressed concerns. Importantly their concerns related to final grades rather than actual ability to solve problems. It may be that PBL facilitation contributes to students' success-related beliefs because the support of the facilitator contributes to mastery experiences which in turn contribute to positive success beliefs.[24, 29]

When facilitators at State U1 put forth effort, students were more likely to believe that they were interested in the project; and as a result, the students more interested in and motivated to engage in their project. In contrast, students at State U2 were not as interested in the workshops and attributed some of their boredom to the failure of the workshop leaders to generate interest. Thus, at both universities, it is clear that the facilitators/workshop leaders had an effect on students' interest.

Finally, PBL facilitation contributed to students' sense of belonging and caring through the team structure, faculty facilitation, and problems that represented realistic engineering work. When participants felt empowered and believed that they could be successful in the course, they felt more connected to and viewed their facilitators/workshop leaders more favorably.

Implications for Practice

Our findings have several implications for practice in project-based environments that highlight specific elements of the PBL framework related to motivation. First, practitioners should consider how they discuss and use grades. When the focus is on a letter-grade, students may attend less to self-directed learning activities (such as asking themselves and group members probative, challenging questions), which could lead to fewer feelings of empowerment and success, resulting in lower motivation. Specifically, even in non-PBL environments, instructors could work towards a guided learning approach rather than an approach based on technical content delivery. Although it is important for students to have technical content knowledge, encouraging them to take control of the learning process will result in more empowered students. This could mean shifting how courses are assessed; taking the focus off of students receiving certain points for completing certain activities with a measure of correctness; and instead, awarding points for engaging in self-directing learning activities such as asking questions. Doing so could have a positive impact on students' motivation and learning approaches.

Second, the role of modeling appears to have a strong impact on students' perceptions of their own work, including their sense of empowerment, their awareness of self-directed learning processes, their beliefs about success, and their ability to connect their work to professional practice. In project-based environments, instructors can consciously adopt such modeling roles, not by solving problems for students but by explaining how they as professionals (or even more advanced students) would undertake the task.

Conclusion and Future Directions

Facilitators in PBL and TED learning environments can influence several factors that affect students' motivation, including empowerment, success, interest, and caring. These findings point to the importance of the role of the facilitators in motivating students. Future researchers should examine how facilitators can best be trained to exhibit behaviors that increase students' perceptions of empowerment, success, interest, and caring.

The fact that several components of the MUSIC Model of Academic Motivation were related to students' motivation provides evidence for the validity of using the model to study students' motivations within this type of environment. Future researchers could examine whether one of these MUSIC components is more important than the others in PBL and TED instruction with first-year engineering students. Further, it would be interesting to examine whether these same MUSIC components are as important to students' motivation in other PBL settings, such as capstone engineering courses and other, discipline-specific courses.

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