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The Effects of a Collaborative Problem-based Learning Experience on Students' Motivation in Engineering Capstone Courses

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Abstract

We identified and examined how the instructional elements of problem-based learning capstone engineering courses affected students' motivation to engage in the courses. We employed a two-phase, sequential, explanatory, mixed methods research design. For the quantitative phase, 47 undergraduate students at a large public university completed a questionnaire that measured the components of the MUSIC Model of Academic Motivation (Jones, 2009): empowerment, usefulness, success, situational interest, individual interest, academic caring, and personal caring. For the qualitative phase that followed, 10 students answered questions related to the MUSIC components. We identified several instructional elements that led to motivating opportunities that affected students' motivation to engage in the courses. We discuss how these motivating opportunities can foster or hinder students' engagement and provide implications for instruction.

Keywords: problem-based learning, motivation, engagement, capstone course, MUSIC Model of Academic Motivation

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Introduction

As problem-based learning (PBL) is implemented in increasingly diverse contexts, educators and researchers need a more robust understanding of how PBL approaches enhance learning in these contexts. Motivation theory provides a useful lens for developing this understanding because it provides a means to analyze students' experiences in ways that reflect their engagement in learning. The results of such analysis can inform the design of PBL environments and contribute to our understanding of the role of PBL in student learning.

One arena that has experienced a surge of interest in PBL is university-level engineering curricula. As Beddoes, Jesiek, and Borrego (2010) note, the emergence of PBL and PBL in engineering dates back at least to the 1970s and the pedagogy has been the subject of a number of recent conferences and workshops. Similarly, the 2003 special issue of the *International Journal of Engineering Education* (IJEE) dedicated to PBL (de Graaff, Kolmos, & Fruchter, 2003) and the 2010 special issue of the *Interdisciplinary Journal of Problem Based Learning* (IJPBL) dedicated to PBL in engineering (Jesiek & Strobel, 2010), attest to the consistently growing interest in using PBL in engineering. This interest aligns closely with current reform efforts in engineering education that emphasize moving from decontextualized presentation of technical content to holistic integration of content and practice (Sheppard, Macatangay, Colby, Sullivan, & Shulman, 2008). PBL is an ideal vehicle for such transformations. As a result, descriptions of PBL in engineering, particularly in design courses, abound. Perhaps the most well-known and well-established PBL work in engineering education is at Aalborg University in Denmark, where PBL is a central tenet of the curriculum (Fink, 1999). The IJEE special issue noted above, for example, includes examples of PBL in microelectronics (Cirstea, 2003) and civil engineering (Mgangira, 2003), while the special issue of IJPBL includes discussions of undergraduate research experiences in engineering through the lens of PBL (Pierrakos, Zilberberg, & Anderson, 2010). Elsewhere, for example, McIntyre (2002) describes the use of PBL in a capstone course in civil and construction engineering, Striegel and Rover (2002) and Knight, Carlson, and Sullivan (2007) describe its implementation in first-year programs, and Cline and Powers (1997) employ it in chemical engineering laboratory courses. LaPlaca, Newstetter, and Yoganathan (2001) have developed a robust PBL program as part of a biomedical engineering program and have seen gains in student performance across the curriculum. Despite an increasing number of descriptive accounts, few articles have provided systematic studies of PBL in these contexts.

Moreover, as engineering faculty employ PBL, they adapt the pedagogy to existing course structures and outcomes. In design settings, in particular, PBL often merges with project-based learning, where the focus is on completing a project that results in the creation of an artifact (Barron et al., 1998; Blumenfeld et al., 1991; Hong, 2007). PBL is often adapted into capstone design courses in the senior year where learning outcomes typically include the ability to synthesize prior knowledge, master new concepts, and enhance technical and professional skills (Pembridge & Paretti, 2010). These adaptations differentiate engineering-based PBL from both its roots in medical schools and its current uses in K–12 curricula, suggesting a potential lack of PBL research in engineering courses. To begin addressing this lack of research, we examined students' motivations in two PBL-based capstone engineering courses. Using a mixed methods approach framed by motivation research and theory, we identified several instructional elements that led to motivating opportunities that affected students' motivation to engage in the courses. In the "Discussion" and "Instructional Implication" sections of this article, we discuss how these motivating opportunities can foster or hinder students' engagement and provide implications for instructors.

Capstone Design Courses in Engineering

Capstone courses form a critical link in engineering education between academic and professional experiences. In the post-WWII era, capstone design was envisioned as a way to help students translate theory-laden course work into the kind of practical work expected by industry (Dutson, Todd, Magleby, & Sorensen, 1997). Numerous researchers have traced trends in design education, identifying common structures, goals, and measured learning outcomes (Howe, 2010; McKenzie, Trevisan, Davis, & Beyerlein, 2004; Pembridge & Paretti, 2010; Todd, Magleby, Sorensen, Swan, & Anthony, 1995). Most relevant for the present study, a recent national survey documented that most faculty who teach capstone courses identified the most important goal of capstone courses as "provid[ing] opportunities for students to synthesize and apply prior coursework in an environment that simulates real world experiences through open ended projects" (Pembridge & Paretti, 2010, p. 8). Given this goal, it is not surprising that the language of problem- and project-based learning has begun to permeate discussions of capstone pedagogy. Most capstone courses rely on facilitation and mentoring as students address real-world, open-ended projects, and the courses typically demand collaborative self-directed learning, critical thinking, and creative problem-solving. Yet, despite rich descriptions and reported successes associated with capstone courses, few studies have systematically examined the effects of specific pedagogical practices, including PBL. As described in the next section, motivation research and theories provide a useful framework to understand how students experience such learning environments and how those learning environments can be enhanced to most effectively support student engagement.

The MUSIC Model of Academic Motivation

Components of the MUSIC Model

To facilitate the use of motivational research and theories in teaching and academic research, Jones (2009, 2010b) developed the MUSIC Model of Academic Motivation. The MUSIC model consists of five components consistently shown to support student engagement in academic settings: e*M*powerment, *U*sefulness, *S*uccess, *I*nterest, and *C*aring. Five key principles of the model are that students are more motivated when they perceive that: they are *empowered*, the content is *useful*, they can be *successful,* they are *interested*, and they feel *cared* for by others in the learning environment. Jones (2009) defines academic motivation

> in a manner consistent with Schunk, Pintrich, and Meece (2008) in which motivation is a process that is inferred from actions (e.g., choice of tasks, effort, persistence) and verbalizations (e.g., "I like biology."), whereby goal-directed physical or mental activity is instigated and sustained. (p. 272)

The *empowerment* component refers to the amount of perceived control and decision making that students have over their learning and is based, in part, on the research related to self-determination theory (Deci & Ryan, 1991, 2000). Instructors can empower students by supporting their autonomy.

The *usefulness* component involves the extent to which students believe that the coursework (e.g., assignments, activities, readings) has utility for their short- or long-term goals. The importance of usefulness to students' motivation has been researched by future time perspective theorists (De Volder & Lens, 1982; Kauffman & Husman, 2004) and by those studying utility value (Wigfield & Eccles, 2000). One implication is that instructors need to ensure that students understand the connection between the coursework and their future 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. Perceptions of competence and expectancy are critical to the motivation theories of many researchers, such as those studying self-concept (Marsh, 1990), self-efficacy (Bandura, 1986, 1997), self-worth (Covington, 1992), goal orientation (Ames, 1992), and expectancy for success (Wigfield & Eccles, 2000). 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 that have been identified by researchers: *situational interest* and *individual interest* (Hidi & Renninger, 2006). Situational interest refers to immediate, short-term enjoyment of instructional activities, whereas individual interest refers to more enduring 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 (Bergin, 1999). 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 (Hidi & Renninger, 2006).

The *caring* component includes two components: *academic caring*, associated with the degree to which students believe that the instructor cares about whether they succeed in the coursework; and *personal caring*, associated with the degree to which the instructor cares about their well-being (Johnson, Johnson, & Anderson, 1983; Noddings, 1992). To support academic caring, instructors can demonstrate that they care about whether students successfully meet the course objectives, such as by: showing concern for students' successes and failures, listening to and valuing students' opinions and ideas, or devoting time and energy to helping students (Jones, 2009). To support personal caring, instructors can demonstrate that they care about students' general well-being and welfare by "making reasonable accommodations for students who experience extraordinary events in their personal lives" or showing "concern about and interest in students' lives" (Jones, 2009, p. 280).

Jones (2009) contends that students can be motivated in a course even when all of the MUSIC model components are not perceived to be present at high levels. However, to increase the chances that that all students will be motivated, he recommends that instructors try to increase students' perceptions of all of these components.

Strengths of Using the MUSIC Model

One of the strengths of using the MUSIC model is that it serves as an operational guide to translate and organize motivational theories and research into practical strategies that can be applied by instructors. The MUSIC components were named intentionally to be descriptive to instructors and to avoid jargon that is familiar to academic researchers but that can be confusing to instructors (e.g., self-efficacy, self-concept, utility value). It is important to note that the MUSIC model does not include new motivation constructs; rather, it was developed based on an analysis, evaluation, and synthesis of motivation research and theories because the components explained unique facets of students' motivation (Jones, 2009). In fact, results from factor analyses provide empirical evidence of the construct validity of the MUSIC model and further show that the components of the model are correlated, yet distinct constructs (Jones & Skaggs, 2012; Jones & Wilkins, in press). Although the MUSIC model incorporates components similar to other motivation models, it is unique in that it has been empirically tested and that it is situated in more recent research and theoretical frameworks. For example, motivational strategies related to empowerment and caring are made more prominent in the MUSIC model than in some models because of the increased recognition of their importance in motivating students (e.g., Bergin & Bergin, 2009; Deci & Ryan, 2000; Noddings, 1992).

Another strength of the MUSIC model is that each of the components can be assessed to examine students' motivations in learning environments. Assessing students' perceptions related to the MUSIC components can be useful to instructors who want to improve their instruction, as well as to researchers studying students' motivations. Students' perceptions of the MUSIC components have been assessed through the use of quantitative questionnaire items (Jones, 2010a; Jones, Ruff, Snyder, Petrich, & Koonce, 2012), qualitative questionnaire items (Jones, Watson, Rakes, & Akalin, 2012), and interviews (Evans, Jones, & Akalin, 2012; Matusovich, Jones, Paretti, Moore, & Hunter, 2011).

The MUSIC Model and PBL

As the description of the MUSIC model suggests, the model components and the motivation research and theories that undergird them dovetail closely with the structure of PBL environments. For example, Barron et al. (1998) identify four general principles central to the success of PBL approaches:

1. Learning-appropriate goals,
2. Scaffolds that support both student and teacher learning,
3. Frequent opportunities for formative self-assessment and revision, and
4. Social organizations that promote participation and result in a sense of agency. (p. 273)

Similarly, Hmelo-Silver (2004) describes the general arc of PBL for students as follows: guided by faculty facilitators, move through the process of structuring the problem by identifying relevant facts, generate hypotheses regarding possible solutions, and identify knowledge gaps. They engage in self-directed learning to gather and share new knowledge, and re-evaluate the hypotheses in light of their new knowledge. The process typically ends with reflection. As facilitators, teachers guide students through developing problem-solving and collaboration skills. Problems are designed to be complex, ill-structured, reflective of realistic practice, and framed to promote knowledge acquisition, problem solving, self-directed learning, and interest.

Such definitions point to potential intersections between PBL and the MUSIC components—intersections that have not been fully explored in the PBL literature to date. PBL can empower students by providing an environment that fosters self-directed learning and collaborative problem-solving, which allows students to make decisions and exert control over their work. Problems that allow students to gain knowledge and skills useful for the real world should increase the likelihood that students will engage in the course, learn that knowledge, and obtain those skills. Collaborative learning and facilitator support can contribute to students' success beliefs by allowing students to engage in mastery experiences (Bandura, 1986, 1997). Further, the complex problems in PBL typically place all students on a relatively equal playing field with respect to skills and knowledge, alleviating task-orientation issues that can disadvantage some students. This approach can support all students' beliefs in their potential to succeed. PBL environments can increase students' perceptions of usefulness and interest by situating technical content within issues of social, personal, and professional relevance. The reflective components of PBL can also contribute to higher levels of individual interest by helping students explicitly articulate their growing understanding of the work that professionals in their field do. Finally, PBL environments can contribute to students' sense of caring as facilitators provide guided mentoring and students learn to depend on one another for learning.

Although prior studies of PBL have explored specific motivation constructs such as self-efficacy (Bédard, Lison, Dalle, Côté, & Boutin, 2012; Dunlap, 2006) and specific components of course design such as group processes and student resources (Henry, Tawfik, Jonassen, Winholtz, & Khanna, 2012), few if any studies have provided a holistic exploration of established motivation constructs and concrete elements of PBL pedagogies such as the one described in this study. It is noteworthy that while the descriptions of PBL such as those provided by Hmelo-Silver (2004), de Graaf and Kolmos (2003), and Savery (2006) suggest that PBL can foster students' positive perceptions of the MUSIC components, poorly implemented PBL can risk fostering negative perceptions. For example, facilitators who do not provide the appropriate amount of guided mentoring could lead to students who are frustrated, unmotivated, and unable to achieve the course objectives. Savery (2006), in particular, cautions against the misapplication of PBL and notes that such misapplications are often the source of learning outcomes that fail to meet expectations.

These general connections between motivation and PBL make the MUSIC model a useful lens for exploring how and why PBL supports student motivation and learning in specific contexts, which can provide guidelines for designing effective learning environments. Although research, such as that discussed previously, contributes to the connections between PBL and motivation research, few studies have examined motivation in engineering PBL environments empirically. In one such study of a well-established PBL program for first-year biomedical engineering students, researchers found that faculty roles supported students' success beliefs, interest, belonging, and caring (Matusovich et al., 2011). Studies such as these provide some evidence to justify further exploration of the connections between PBL and engineering students' motivations.

Research Question

The apparent intersections between motivation and the structure of PBL environments, the limited empirical evidence for these intersections, and the increased adoption of PBL in engineering curricula all point to the need for more robust comprehensive studies of the role of motivation in PBL, especially in engineering contexts. To that end, our research question was: How do the elements of PBL-based capstone engineering courses relate to students' motivation to engage in the courses?

Method

The Mixed Methods Research Design

We employed a two-phase, sequential explanatory mixed methods research design that consisted of two distinct phases: a quantitative phase followed by qualitative phase (Creswell & Plano-Clark, 2011; Ivankova, Creswell, & Stick, 2006). In the quantitative phase, we collected and analyzed questionnaire data that was used to select participants through purposeful sampling for the qualitative phase (Creswell & Plano-Clark, 2011). In the qualitative phase, we collected and analyzed qualitative interview data.

Study Site

The study site consisted of two year-long capstone engineering courses (referred to simply as Capstone A and Capstone B) at a mid-Atlantic U.S. university; data collection occurred only during the middle of the fall semester of the year-long courses that continued into the spring semester. Capstone A included 31 students in 9 groups and Capstone B included 25 students in 7 groups. The courses were situated in different engineering departments but were taught by the same instructor and shared the same pedagogical approach, assignments, and schedule. Students worked in groups to complete an open-ended, ill-structured project appropriate to their engineering field. These courses were designed to allow students to integrate and apply knowledge from prior courses, as well as identify and learn new knowledge needed for the project. Students had to demonstrate technical science and engineering skills, as well as professional skills such as teamwork, communication, project management, self-directed learning, and ethical practice. Thus, the courses bridged students' classroom experiences in problem solving and the collaborative design work anticipated in industry.

As is common in capstone courses, these courses included both an instructor and faculty advisors. The female instructor, who was well-versed in the principles of PBL, served as the course coordinator and "project manager," helping students define, plan, and implement an extended open-ended project. She provided mini-lectures and individualized group feedback that addressed core issues such as project planning, definition of deliverables, budgeting, product communication, and teamwork. Groups were required to develop charters regarding appropriate group behavior, including time commitments, and the instructor encouraged the groups to establish a weekly meeting time that worked for the entire group.

Students met with the instructor together in class twice a week, and met with their groups outside class to work on their projects. Though project-based, rather than problem-based, the courses were intentionally structured using the principles of PBL in terms of both the role of the instructor and the manner in which students were guided through the project. Although several scholars distinguish between problem- and project-based learning (e.g., Barron et al., 1998; Hong, 2007; Hmelo-Silver, 2004; Savery, 2006), particularly through emphasizing the production of an artifact constrained by product specifications, work in engineering education points to the close link between the two (Beddoes et al., 2010; de Graaff et al., 2003). In addition, the nature of the disciplines in this particular case lent themselves to a number of projects that were more research-based problems than artifact-based projects; only three of the projects had products as end goals. The course projects in this case meet most of the following characteristics outlined by Savery (2006).

- The courses were explicitly learner-centered, with students responsible for designing the goals and approach and taking responsibility for identifying the necessary learning and professional development.
- The projects were all ill-structured, involving novel research questions situated in the professional practice of the students' fields.
- Although the capstone courses were each situated within a single engineering discipline, the projects typically required students to branch out into other science and engineering fields to effectively carry out the work.
- All projects in the two courses were collaborative; all projects involved at least three team members with one exception (one two-person team was allowed in Capstone B).
- The projects relied heavily on iteration of practices and redesign of experimental methods and procedures based on results from trial studies.
- The courses included regular student reflections on both their own learning and the team process; these reflections, included at the beginning, middle, and end of the projects, incorporated both self and team assessment.
- The projects were closely aligned to students' expected work practices, and the course projects in Capstone A were reviewed annually by an external industry advisory board to ensure this alignment.
- Although evaluation focused heavily on team processes and project progress, student learning and development were a key factor in the assessment.
- The courses were centered on the project; the didactic component was limited to minimal supplemental lectures to provide general just-in-time guidance.

In addition to intentionally aligning the course work with the components of PBL, the course instructor was well-versed in the literature on PBL facilitation, particularly as delineated by Hmelo-Silver and Barrows (2006, 2008) and employed strategies such as metacognitive questioning, pushing for explanation, revoicing, summarizing, and generating and evaluating hypotheses. The instructor interacted with the student teams regularly in class (often providing focused time for teams to work in class on their projects), through written communication (regular email correspondence as well as formal reports and presentations), and during at least two individual team meetings a semester. In all of these interactions, the instructor focused on discourse that promoted student learning and student ownership, with an emphasis on questions rather than directives.

Each group also worked with a technical faculty advisor from their departments. Advisors typically focused on supporting students' technical performances by providing articles to read, suggestions for data collection and analysis, and feedback, though some also supported project management. It is important to note, however, that these advisors were not explicitly trained in PBL facilitation. Students had the option of (a) developing their own ideas for their design project and then locating an advisor willing to work with them or (b) choosing a project already created by a willing advisor. Students in both courses selected their projects during the spring of their junior year and worked in groups of two to five students. Of the nine teams in Capstone A, one team worked with their advisor to develop a project based on their interests and the advisor's expertise, and two teams developed projects based on prior undergraduate research that several team members had conducted with the advisor; the other six teams worked on projects developed primarily by the advisor. Among the seven teams in Capstone B, two projects were entirely student developed and driven, while the other five were created by the respective advisors.

Quantitative Phase

Participants. Thirty of the 31 students (96.8%) in Capstone A and 17 of the 25 students (68.0%) in Capstone B completed the questionnaire. Of these 47 students, 14 (29.8%) were female and 33 (70.2%) were male. Most self-identified as White (91.5%), whereas 6.4% selected Asian or Pacific Islander and one selected "Other." All participants had senior standing and most planned to graduate in the upcoming spring.

Procedure. The questionnaire was administered online in the middle of the fall semester, after the groups had drafted and received feedback on their project proposals, and after they had completed the first reflective assignment that asked them to evaluate their current learning status (the skills they brought to the project) and the learning gains they hoped to achieve. Thus, the timing of the questionnaire administration allowed us to capture students' perceptions in the midst of the project rather than at the end, when the project's overall success or failure could skew students' in-the-moment perception. At the proposal phase, students had generally developed a sufficient understanding of the project, including both learning relevant background information (prior research on the subject and new concepts), identifying issues that required new learning (laboratory or analytical techniques, subdomains in their field to explore), and mapping out project goals as well as a general project plan. Moreover, at this phase, most teams had begun setting up experimental work; and thus, were "in process" on the project work itself. Students in Capstone A completed the questionnaire during a regular class meeting; due to time constraints, students in Capstone B were invited via email to complete the questionnaire outside class, with two reminder emails.

Instruments. We used the instruments presented in Jones (2010a) to measure the seven MUSIC components: empowerment (5 items), usefulness (3 items), success (4 items), situational interest (3 items), individual interest (3 items), academic caring (4 items), and

Table 1. Cronbach alphas, means, standard deviations, and ranges for each MUSIC model component

MUSIC Model Component	Example Item	α	M (SD)	Range
Advisor Empowerment	My advisor listens to how I would like to do things.	.89	5.89 (0.83)	3.60–7.0
Teammate Empowerment	My teammates listen to how I would like to do things.	.89	6.01 (0.73)	3.20–7.0
Usefulness	In general, the project is useful to me.	.92	5.47 (1.11)	1.67–7.0
Success	During this project, I have felt confident in my ability to learn the material.	.84	5.64 (0.76)	3.50–7.0
Situational Interest	In general, how interested are you in the project?	.92	5.54 (1.03)	2.33–7.0
Individual Interest	What I learn by participating in the project is very valuable to me.	.84	6.04 (0.92)	1.67–7.0
Advisor Academic Caring	I believe that my advisor cares about how much I learn.	.73	6.39 (0.56)	5.25–7.0
Teammate Academic Caring	I believe that my project teammates care about how much I learn.	.70	6.11 (0.70)	4.50–7.0
Advisor Personal Caring	I believe that my advisor really cares about me as a person.	.85	5.76 (0.96)	3.25–7.0
Teammate Personal Caring	I believe that my project teammates really care about me as a person.	.93	6.10 (0.95)	3.00–7.0

Note: All items were rated on 7-point Likert-type scales personal caring (4 items). Empowerment, academic caring, and personal caring were measured in relation to both students' advisors and their teammates, increasing the total number of components to 10. Because the engineering courses in this study differed from the courses in Jones (2010a), the wording was altered slightly in some cases to match the context more closely (e.g., the word "course" was changed to "project). All items were rated on 7-point Likert-type scales and an example item for each instrument is provided in Table 1. The reliability estimates for all of the scales were acceptable (see Table 1 for the Cronbach alpha values).

We measured empowerment using five items from the short version of the Learning Climate Questionnaire (Williams & Deci, 1996) that measures the degree to which students perceive their advisor (or teammates) as supporting their autonomy. We measured usefulness using a 3-item utility value scale used by Hulleman, Durik, Schweigert, and Harackiewicz (2008) to measure the extent to which students perceived the courses to be useful to their life and future. We measured success using the 4-item Perceived Competence Scale (Williams & Deci, 1996; Williams, Freedman, & Deci, 1998) to assess students' feelings of competence in the course. We measured situational interest with a 3-item scale used by Jones (2010a) that included items similar to those used by other researchers (e.g., Simpkins, Davis-Kean, & Eccles, 2006; Wigfield & Eccles, 2000) to measure "intrinsic interest value" and "situational interest." This scale measures the extent to which students enjoy and are interested in the course. We measured individual interest with a 4-item "Devaluing" scale (Schmader, Major, & Gramzow, 2001) that was reverse coded by Jones (2010a) to measure the extent to which students found the courses to be important and valuable. We measured academic caring using the 4-item Teacher Academic Support scale and personal caring using the 4-item Teacher Personal Support scale, both of which are subscales of the Classroom Life Instrument (Johnson et al., 1983). These scales measure students' perceptions of their advisor's (and teammates') support in the academic and personal dimensions, respectively.

Qualitative Phase

Participants. Fourteen of the questionnaire respondents (six from one course and eight from the other) indicated that they would be willing to allow us to interview them regarding their experience in the course. We randomly selected five students from each course ($n = 10$) to participate in the interviews. Two of the authors conducted the interviews and each interviewed two participants from one course and three from the other.

Procedure. Each participant was interviewed once for no longer than 45 minutes; the interview protocol appears in the Appendix. The semi-structured interviews addressed student experiences and perceptions of motivation. Data analysis for the interviews began during the interviews with probing and follow-up questioning. All interviews were audio recorded and transcribed verbatim. We employed the constant comparative analysis method to analyze the data (Corbin & Strauss, 2008). Investigator triangulation enhanced the reliability and trustworthiness of the data (Patton, 2002). Three of the authors coded the ten transcriptions individually; coded transcripts were then compared to achieve consensus. Inconsistencies were discussed and the categories and definitions were revised accordingly. To establish trustworthiness, all participants examined the transcript generated from their semi-structured interviews to determine the accuracy and credibility of the account. Finally, the use of rich and thick descriptions within the qualitative findings helped to ensure confirmability and transferability of the qualitative data.

Results and Findings

Table 1 lists the Cronbach alpha values, mean values, standard deviations, and range of responses for the MUSIC components. The means are all relatively high, ranging from 5.47 to 6.39 on a 7-point Likert-type scale.

We conducted qualitative, semi-structured interviews to discover which elements of a collaborative PBL experience were salient to students' motivation. Three categories emerged from the analysis of the qualitative data: Project Design, Group Experience, and Project Advisor. Each category is comprised of three or four instructional elements and we used these categories and elements as a framework for organizing the qualitative findings presented in this section. Each instructional element provided a "motivating opportunity" because participants described how that element fostered or hindered their motivation. That is, the element provided the opportunity to motivate students, but it did not necessarily contribute to all students' motivation. Further, the motivating opportunity did not always lead to students becoming more motivated; in some cases, students became less motivated because of what they experienced as a result of the motivating opportunity. Thus, we use the term "motivating opportunity" simply to refer to the element of instruction as one that students reported as being motivating or not motivating to them during the project.

Although we report the results of the categories and elements within each category separately, the elements were not necessarily experienced independently of one another; rather, they were likely experienced holistically. We discuss each element separately, however, in an attempt to understand the different elements that comprise a student's experience in this type of PBL environment. To further elucidate how the instructional elements can motivate students based on our expertise with and understanding of the MUSIC model components, we identified the key MUSIC model components that appear most closely linked (in either positive or negative ways) to the instructional element and motivating opportunity. We labeled these MUSIC model components as "key" because they are the ones that were most often linked to instructional elements in the participants' responses. However, it is likely that these key components would also affect other MUSIC model components. In Table 2, we provide a summary of the categories, instructional elements, motivating opportunities, and key MUSIC model components.

Project Design

One element of the collaborative PBL experience that influenced the participants' motivation was their ability to select a project. This instructional element, Project Selection, provided four different types of motivating opportunities (see Table 2). Four participants indicated that they selected their project based on their interests, whereas two participants selected an advisor before they selected a project. In both instances, participants suggested that having the ability to select their project and/or advisor was an empowering element within the PBL design. Six participants selected projects based on individual interests that were tied to their career plans. Kevin indicated that his interest in the topic is what led him to his group: "Two girls had partnered up and were talking about this idea. It sounded interesting to me, and so I joined their group." In cases where the project topic was not related to individual or career interests, two participants experienced low motivation. For one particular participant, the lack of interest was linked not only to the project, but also to engineering because during her undergraduate career her career interest shifted. She discussed her low project interest in the following: "I'm generally an apathetic engineer, I'm just trying to get done . . . don't find the topic interesting." Other students selected an advisor before they selected a project, as explained by Jack: "We picked who we thought would be a really good advisor, and then we talked to him about what would make a good project." These students appeared to make their decision based more on the success that they could achieve with a caring advisor that would help them achieve that success. Two participants were less motivated because none of the available projects aligned with their interests and one participant indicated that he had difficulty finding an advisor for his chosen topic who was not already advising other groups.

Another reason that three students selected their project was that they felt it would make a contribution to the greater good. The usefulness of the project to others beyond the course was motivating, and these participants expressed satisfaction in knowing that their findings could positively affect others. "We knew that we wanted [our project] to be something that could impact the world, so we chose desalinization [as the topic] in order to have an impact that people could see," Emily recalled.

Seven participants also selected a project that was useful for their longer-term career goals. Whether they intended to pursue graduate school or industry employment, the capstone project provided these participants an opportunity to explore possible careers, as explained by James:

Table 2. Categories, instructional elements, motivating opportunities, and key MUSIC components impacted

Categories and Instructional Elements	Motivating Opportunities	Key MUSIC Model Components Impacted
Project Design		
Project Selection	Opportunity to select a project based on their individual interest	Empowerment, individual interest
	Opportunity to select a project based on the ability of a caring advisor to help them complete a successful project	Empowerment, success, academic caring
	Opportunity to select a project based on the usefulness of the project to others	Usefulness
	Opportunity to select a project based on the usefulness of the project to their career goals	Usefulness, individual interest
Project Type	Opportunity to work on a realistic, "real-world" project	Usefulness
Project Scope	Opportunity for application and synthesis of knowledge	Usefulness
Project Control	Opportunity to be in contr ol of and make decisions about the project	Empowerment, success
Group Experience		
Group Selection	Opportunity to select their group	Empowerment, individual interest
Group Functions	Opportunity to have control over some aspects of group functioning	Empowerment
Group Interactions	Opportunity to interact with other students in small groups	Situational interest, academic and personal caring, success
Project Advisor		
Advisor's Guidance	Opportunity for advisors to provide help students make decisions	Empowerment, success
Advisor's Feedback	Opportunity for advisors to provide feedback about project progress	Success
Advisor's Interactions	Opportunity to have a close relationship with an advisor	Success, academic and personal caring, situational interest

> Our project is around nuclear fuel palette research and design. That's really helpful to me because I want to go into the nuclear industry. I get to walk into job interviews and say, "My senior design project is what your company does." I'll walk into the job, and I've already done half the stuff that the senior engineers are working on.

Two participants, however, felt that the project did not relate to their long-term career goals; participants interested in careers outside engineering did not find the project useful, which decreased motivation and effort.

Seven participants were motivated by Project Type. Because these participants felt that the problem-based experience was a realistic simulation of a "real-world" work experience, they found it to be useful for their future goals. "I've interned in research companies, and it's pretty similar. I think it's pretty realistic, honestly," acknowledged Kevin. This realistic nature of the project included engaging in the research process, working in a laboratory setting, communicating with their colleagues during a group experience, and addressing real-world challenges and issues. Henry indicated that, for him, the realistic nature of the project was a positive experience. "One thing I like about the project is they emphasize that what you're doing in this capstone mimics the real world. You're going to be working with projects. You're going to have to deal with people, and they emphasize that," he said. Three participants, however, identified conditions they believed to be unrealistic, and thus, not useful. This included the amount of paperwork during the proposal process, having an advisor who supervised them, and teams of individuals who all had the same expertise (rather than a group with different backgrounds).

Another motivating element of the instruction was the Project Scope. Two participants shared that the PBL experience provided them with an opportunity to apply and synthesize the knowledge that they had gained in prior course work. The participants found the project useful because it provided them with practical experience and the chance to apply knowledge gained across their undergraduate coursework to a single problem. As Mia noted:

> We have to take all of the things we've learned in the past four years and apply them to one project. We don't have a piece of paper saying these are the equations you need to use. We are having to sit down and break down all that stuff on our own for the first time.

Project Control was also an important element in motivating some participants. Seven participants indicated that their group exercised a high level of control over the project direction and goals beyond their advisor's instructions, fostering motivation through empowerment. When asked about the amount of control their group had, Ben offered the following explanation:

> Our advisor would advise us and would listen to our ideas and say, "Okay, how can I help? How can I help achieve the end result?" I think we felt that our voice was heard and then that our advisor would then step back and steer us in the right direction if we were heading towards a direction that wouldn't produce good results or if we were not doing things according to engineering protocol.

Additionally, four participants indicated they had empowerment over the timelines for work completion. For example, one group decided to complete assignments two days before the due date to avoid emergencies and have control over the project workload, making it less intimidating. Control was also related to knowledge: when participants felt that the project was within their abilities and they knew what they had to do, they perceived that they had control over their success; in contrast, a lack of control of their ability to be successful was linked to a lack of knowledge.

Group Experience

Working together with three other students in a group provided a few different types of motivating opportunities (see Table 2). The Group Selection element relates to how project groups were formed. Three participants experienced motivation because they were empowered to select their group members, and three stated that they chose group members based on common interests rather than friendships. For instance, Tanya recounted what led her to her group: "I wanted to do something for my senior design capstone project that was something I was interested in over choosing my friends." When asked how his group formed, Jay offered the following description:

> [Student name] mentioned that she wanted to work with polymers. I was like, "I think that's a really good idea. I like it." Then, [student name] was also interested in polymers, so she joined the group. [Student name] mentioned that he didn't have a group. I said, "Hey, we're doing polymer desalination membranes." He said, "Would you care if I join you guys?" He joined the group that way.

The Group Functions element provided other opportunities to motivate students. Five participants felt that the PBL course design provided them with empowerment regarding group functioning and work allocation. Four participants indicated that the group members had equal say and that their group took a democratic approach to group functioning.

For example, Julia acknowledged the autonomy her group had in determining how work was completed. "We sit down and go over what happened last week, and that turns into 'What did our advisors say that we need for this week?' Then we say, 'What's due when? What do we need to accomplish first?'" Each group collaboratively decided how to divide the required work, and many participants expressed satisfaction with the work allocations.

Some participants indicated that their Group Interactions were motivating through the fun that they had together, the caring relationships that were formed, or both. Five participants enjoyed the excitement of working with other students that had similar interests (that is, it was situationally interesting). For example, when William was asked how working in a group has influenced him, he expressed that "it helps with my motivation." Even so, working with a group did not motivate all participants, and four indicated that their group members did not influence their interest or motivation.

Of the four participants who described their group interactions as caring, some used words such as "close-knit." Because everyone was committed to maintaining a functional group, it was easier for participants to work together, and participants were more comfortable asking one another questions. These participants believed that their groups had a strong work ethic derived from each member's dedication to the success of the project: they listened to one another, offered advice, and cooperated. "It's gone pretty well. We haven't had any issues or anything like that – we haven't had problems with anybody not doing their work," said Kevin. Other examples included respecting one another, valuing communication during group interactions, caring about every group members' participation, assisting each other in different parts of the project, assisting one another with time management, helping each other be more responsible, and relying on one another's different knowledge areas and expertise. These participants believed that all group members cared about succeeding academically.

Three participants viewed their group members more as friends than teammates. They cared for each other personally and knew about one another's lives outside of the school context. These participants believed that working on projects with others was enjoyable (although it did not necessarily influence group members' sense of interest or responsibility). In some cases, participants developed rapport with their group through the project and felt they had a cohesive group with a community mindset. One group worked to create a friendlier environment by having dinner together when they were stressed.

Five participants felt they could handle conflicts successfully because group members respected each other and were willing to listen to one another. They believed that listening helped create positive group dynamics, especially when group members were under stress. Further, the feedback that participants received from group members contributed to the success of the group, as is discussed further in the Advisor's Feedback section below.

In contrast, four participants perceived only a working relationship with their fellow group members. "It's a working relationship. We are on speaking terms, but just business speaking terms. There is not really any outside communication beyond the project," stated Molly. Although these groups did not socialize outside the project or form close-knit personal bonds, the participants perceived that these "professional" group dynamics still resulted in academic success and were satisfied with their group experience. This suggests that, although personal relationships contributed positively to the project experience, the participants did not perceive personal bonds as crucial to success.

Project Advisor

Participants indicated that their Project Advisor was an important aspect of their motivation. The element Advisor's Guidance refers to the amount of help that the advisor provided and number of decisions that he or she allowed the students to make on their own. Three participants described their advisors as having a "hands-off" approach, in which their advisors let their group make many of the decisions and find the required answers. One participant mentioned that the lack of guidance from her advisor gave her a sense of ownership over the project. In contrast, two participants felt paralyzed by the resulting uncertainty and questioned their ability to be successful. These participants expressed frustration and disempowerment with this distant approach, wanting, for example, more guidance on their proposal. Jason noted: "Our advisor has been pretty hands-off. We knew going into it that our advisor would be pretty hands-off. It's been good in some aspects; it's been absolutely terrible in other aspects." He further explained:

> When we did the rough draft of our proposal, we were missing so many elements. We had no idea until we went and talked to the course instructor, and she said, "You're missing so many things." We just had no idea what we were missing.

When asked if the hands-off approach was motivating or overwhelming, Jason said:

> It empowers us because it's allowed us to take the project where we want to, and forces us to take this project as a real project. There are no real bounds to it. The problem is that this project is so above our heads that we were pretty lost for the first few weeks and had zero guidance. It was a lot of hard work on our part to try to understand the material.

In another instance, Julia stated that her project advisor was involved, but added assignments beyond the course requirements, which created frustration. Instead of helping the group find needed answers, the extra assignments seemed to sabotage work by taking up valuable time.

Some participants indicated that their Advisor's Feedback was also linked to motivation, though the degree, nature, and value of the feedback varied. Three participants benefited from their advisor's feedback because it led to the perception that they could be successful. Three groups had difficulty obtaining feedback from their advisors, and one group had not received any advisor feedback at the time of the interview; this lack of feedback was seen as a barrier to the success of the group.

Some participants contrasted their advisor's feedback with that received from their group members. Two students identified peer feedback as less helpful than their advisor's and instructor's feedback because their group members were also trying to learn the material. As Kevin said, "We don't get a whole lot [of feedback] from our group members considering we work together on stuff . . . we're all learning at the same time. The instructors and advisors come from a place of knowing what they're talking about." In contrast, Molly indicated that peer feedback had contributed more to the group's success than advisor or instructor feedback. Experiences with advisor feedback were similarly varied.

Advisor Interactions were described as a motivating element, often because they could enhance feelings of success and academic and personal caring. Four participants felt that their project advisor wanted them to be successful. For example, Ben expressed how the support from the project advisors motivated him. "I know that our advisors are a hundred percent behind us. They want to see us succeed, and it makes me feel good about the project. . . . I feel pretty confident that we have full support of our advisors." In addition, three participants described specific actions that led them to believe their advisor was supportive. This was demonstrated by providing students with time (face to face, Skype, email, etc.), offering guidance, and being engaged in the project. Two participants perceived their advisors as helpful when they offered to assist them during different aspects of the project and helped them to overcome obstacles such as material acquisition. Additionally, six participants believed that their advisors cared about the groups' learning and the progress of their work, and they felt that their advisors fully supported the group and wanted them to succeed. "[Our advisor] knows our group wants to do the best possible, and she warns us it may not succeed, but just try to get as far as you can and get something out of it. If you get anything, it's good enough," explained Emily. Finally, positive interactions were reported when project advisors took time to meet with their group, when they listened to the group's ideas, provided the group with constructive feedback, and were available when the group encountered problems. When groups faced problems outside the advisors' specialization, caring advisors still provided general guidance. Six participants' perceptions were that although these advisors held the group accountable to complete the work, they also demonstrated respect for the participants' knowledge and abilities.

In contrast, Julia indicated that her group's relationships with their advisors were "rocky." The relationships improved over time, but her group members avoided talking with their advisors because they feared confrontation. Two groups viewed their advisors' comments as "offensive"; consequently, Julia's group relied on graduate students for help instead. Molly felt her project advisors were not helpful and they did not provide the group with any feedback. When asked what she would change about her advisors' involvement, she said her group wanted straightforward answers at critical points, and they wanted their advisors to provide guidance when it was requested. "Occasionally answering a 'yes' or 'no' question with a 'yes' or a 'no' would be very nice. For some things, we spend days searching, and we never come to any conclusions because we don't get a 'yes' or 'no' from our advisor," she explained.

In addition to interactions related specifically to the project, one participant indicated that his relationship with his advisor was enjoyable (that is, situationally interesting), and during meetings they talked about issues beyond the project. Another participant enjoyed meeting with his advisor in order to generate ideas, and yet another participant appreciated his advisor treating his group members as responsible adults. In one clear instance of a caring relationship, James said:

> One advisor does a good job of not only being a good mentor, but she creates a really friendly atmosphere. You feel like you're there to learn something. I really feel like [I'm] sitting there with my mom. Even with [advisor's name], he's the head of our department, and it really feels like I'm just going and meeting with my grandfather. I think they just fill that mentor role really well.

Three participants believed that their advisors tried to be mentors and transfer their knowledge and experiences to their group. Two participants also believed that their advisors cared about their personal well-being, evidenced, for example, by helping students plan well to avoid becoming overwhelmed and by providing constructive criticism. In contrast, three participants did not have a close relationship with their advisors, indicating, for example, that their advisors did not know their names, which in turn impeded communication. "I don't even think [my advisor] knows my name. That can be a big challenge," said Jason. In one case, participants were not sure if their advisor's hands-off approach was a sign of respect for students or simply a result of the advisor's busy schedule.

Discussion

We collected and analyzed quantitative and qualitative data to examine how the elements of PBL-based capstone engineering courses related to students' motivation to engage in the course. We used the components of the MUSIC Model of Academic Motivation to guide our data collection and analysis because these components are associated with students' motivation and engagement in academic environments (for a discussion, see Jones, 2009). The quantitative questionnaire data allowed us to examine students' overall perceptions related to each of the MUSIC model components, whereas the qualitative interview data allowed us to understand how the instructional elements of the courses can provide motivational opportunities that relate to students' motivation to engage in the course.

Elements Relevant to Students' Motivation

The means presented in Table 1 indicate that, on average, students reported high values for the MUSIC model components. These results provide evidence that most students were, on average, motivated during the courses. In this respect, the elements of the PBL-based courses appear to be successful at motivating students in the courses given that the MUSIC model components have been consistent predictors of students' motivation in a variety of higher education courses (Jones, 2009). However, the range of responses provided for any one MUSIC model component vary fairly significantly, indicating that students can perceive these components quite differently, as we discuss in the "Individual Differences" section below. One limitation of the instruments used in the present study was that they were developed and validated by different researchers at different times for different purposes. Since the time of the present study, Jones and Skaggs (2012) have developed an inventory that has produced valid scores with college students for each of the MUSIC model components. Using inventories such as this that were designed to measure the MUSIC components might provide scores that are more valid when compared across MUSIC components (e.g., comparing an empowerment score to a usefulness score).

To understand how the students discussed their motivations in their own words and how these discussions aligned with the quantitative data, we analyzed the interviews with our 10 participants and searched for themes. Our findings indicated that PBL offered students many motivating opportunities that we categorized into three broad themes: Project Design, Group Experience, and Project Advisor. As shown in Table 2, we divided these three categories into several different elements and motivating opportunities. It was through these motivating opportunities that students' perceptions of the MUSIC model components were affected. The motivating opportunities provided moments for students to perceive that they were empowered, that the project was useful, that they could be successful, that they were situationally interested, that they were able to relate the project to their individual interests, and that they felt cared for academically and personally. We identified at least one key MUSIC model component that was impacted by each motivating opportunity, with some opportunities impacting up to three key MUSIC model components. The amount and variety of motivating opportunities presented to students in these PBL courses indicates that PBL offers many opportunities to affect their perceptions about the MUSIC model components in these courses. We believe that this is a

Table 3. Relationships between the motivating opportunities and each MUSIC model component

Motivating Opportunity	MUSIC model component
Project Design • Opportunity to select a project based on their individual interest • Opportunity to select a project based on the ability of a caring advisor to help them complete a successful project • Opportunity to be in control of and make decisions about the project Group Experience • Opportunity to select their group • Opportunity to have control over some aspects of group functioning Project Advisor • Opportunity for advisors to provide help students make decisions	Empowerment
Project Design • Opportunity to select a project based on the usefulness of the project to others • Opportunity to select a project based on the usefulness of the project to their career goals • Opportunity to work on a realistic, "real-world" project • Opportunity for application and synthesis of knowledge	Usefulness
Project Design • Opportunity to select a project based on the ability of a caring advisor to help them complete a successful project • Opportunity to be in control of and make decisions about the project Group Experience • Opportunity to interact with other students in small groups Project Advisor • Opportunity for advisors to provide help students make decisions • Opportunity for advisors to provide feedback about project progress • Opportunity to have a close relationship with an advisor	Success

Table 3 (continued)

Group Experience • Opportunity to interact with other students in small groups Project Advisor • Opportunity to have a close relationship with an advisor	Situational Interest
Project Design • Opportunity to select a project based on their individual interest • Opportunity to select a project based on the usefulness of the project to their career goals Group Experience • Opportunity to select their group	Individual Interest
Project Design • Opportunity to select a project based on the ability of a caring advisor to help them complete a successful project Group Experience • Opportunity to interact with other students in small groups Project Advisor • Opportunity to have a close relationship with an advisor	Academic Caring
Group Experience • Opportunity to interact with other students in small groups Project Advisor • Opportunity to have a close relationship with an advisor	Personal Caring

positive finding in that, unlike some instructional approaches, these PBL courses provided many opportunities for students to become engaged. These opportunities, however, also increase the chances that some students will disengage if the instructional elements are not implemented in a manner that supports students' motivation (e.g., the advisor does not provide adequate support or is not perceived as being caring).

The findings in Table 2 also show that the motivating opportunities occur at various times in the courses. Some of the opportunities are established prior to the start of the course, such as whether or not to allow students to select their project, group, and/or advisor. In the courses examined in our study, the instructor decided to allow students to choose each of these three things; however, another instructor might choose to select these based on some pre-decided criteria or to select the projects, groups, and advisors for the students. Other motivating opportunities were structured at the beginning of the course, but could fluctuate throughout the course depending upon the students, project, and advisor. For example, the students continued to have opportunities to be in control of and make decisions about the project, had control over some aspects of group functioning, had interactions with other students, could receive feedback from the advisor, and interact with the advisor. These types of opportunities allowed for students' motivation to be fostered (or hindered) throughout the length of the project.

To examine the same findings through a different lens, we re-organized the motivating opportunities and key MUSIC model components in Table 2 into Table 3, which shows how the motivating opportunities in each category were related to each MUSIC model component. From Table 3, it is easy to see the categories and motivating opportunities that impacted each MUSIC component. Empowerment was impacted by motivating opportunities in the project design, group experience, and project advisor categories through instructional elements that provided choices and fostered decision-making, such as choosing a project, making decisions about the project, selecting teammates, having control over group functioning, and the extent to which their advisors helped them make decisions. This finding indicates that students' opportunities to feel empowerment can be affected by decisions made by the instructor prior to the start of the course in the project design, as well as throughout the project by the group and advisor.

In contrast, usefulness was only impacted by opportunities in the project design. Thus, once the project topic, type, and scope were determined, there were fewer opportunities to impact students' perceptions about the usefulness of the project. It is likely that as students learn more about their project that they will still have opportunities to see the usefulness of it; however, it might become more difficult to do as the project progresses as compared to near the beginning of the project. Our findings were similar for individual interest in that the opportunities that affected it were primarily ones that were determined near the beginning of the project, such as selecting a project and a group. Success was impacted by elements of the project design, group experience, and project advisor. Because success perceptions are dependent on specific tasks and feedback received during the project, it is logical that the motivating opportunities related to success come from various sources at various points during the project. Situational interest was primarily impacted through interactions with other students and their advisor. This finding demonstrates the importance of the relationships in PBL courses because if these relationships were not going well, students would certainly find their work on the project less situationally interesting. Although we do not believe that instruction always has to be enjoyable to be effective, it is certainly preferable for students to work on a project that they find enjoyable. Similar to situational interest, academic and personal caring were impacted by the relationships between other students and their advisor. The ongoing relationships between group members and the group members and their advisors provided the means to either support or hinder students' perceptions about caring.

In sum, our findings indicate that the PBL project implemented in these courses provided many instructional elements that led to many motivating opportunities for students. The motivating opportunities were present at the beginning and throughout the project and affected all of the MUSIC model components to some extent. These results extend findings from other studies that examine motivation-related constructs in PBL environments. Though work on motivation theory and PBL is still young, some work has been conducted to explore constructs such as self-efficacy (Dunlap, 2006) and engagement (Bédard et al., 2012). For example, whereas Bédard et al. (2012) found no direct predictive link between self-efficacy and engagement in the PBL environment, their work did indicate that supports (e.g., opportunities for personal growth) and reflexive thinking, which align with the MUSIC model constructs, do predict curricular engagement. Their study also documented that stress-related factors were dominant predictors of engagement and persistence, and that autonomy (aligned with empowerment in the present study) was a strong support system; the link here between empowerment and particular course elements such as project selection and control extend the quantitative results evidenced in that work. Similarly, several studies have highlighted the mentor role in student engagement (e.g., Ge, Huang, & Dong, 2010; Henry et al., 2012) and the findings provide a direct link between specific facilitator behaviors and robust motivation constructs.

Individual Differences

Our findings suggest that students can experience the instructional elements and motivating opportunities differently. In this section, we discuss some of these different experiences, acknowledging that these are only some of the possible differences that might result from this type of PBL experience.

From the quantitative questionnaire data, it is evident that the range of scores for each MUSIC component vary. The largest ranges (in order of decreasing magnitude) were for individual interest, usefulness, and situational interest. Some of these ranges are misleading, however, because of a single outlier score; for example, only one student reported less than 4.0 for individual interest. Nonetheless, these results raise the question: Why would students in a senior capstone course in their major find the course uninteresting or not useful? The interview findings offer some insights. Although most students found the project useful because it simulated a real-world experience, others found the paperwork, the role of their advisor, and/or the group environment unrealistic. In addition, despite the fact that the students were engineering majors, some students did not plan to pursue an engineering career; thus, they considered the project less useful and less interesting. The interviews also exposed differences in empowerment, success, and caring. Some students felt empowered for many project tasks, whereas others did not (e.g., they were not able to select a project for which they were interested). Some students found their lack of knowledge or experience to cause them to question whether they would succeed;

others did not like having to rely on teammates for their success. Finally, some students found that their relationships with their advisor and/or teammates problematic, which reduced these students' perceptions of academic caring.

These findings indicate that the most difficult students to motivate in this context, even within a PBL pedagogy, are those not engaged in the content, either because it does not match their career goals or because they do not believe the environment matches the real world. In a previous section, we noted that the usefulness and individual interest MUSIC components were most impacted by motivating opportunities in the project design and ones that occurred earlier in the project. Given this, it appears that it is critical to design the project in a manner that can be seen as useful and relate to as many interests as possible if the intention is to fully motivate students. The instructional implications below offer some other possible strategies for more effectively deploying PBL in this context to better engage all students.

Instructional Implications

Although it is unlikely that instructors can motivate students all of the time, the results of this study suggest some ways in which instructors can enhance the PBL environment to increase student motivation. These guidelines should extend to other PBL contexts, though additional study may be needed to more closely target guidelines to contexts. While these implications align with motivation-based recommendations for course design such as those described in the MUSIC model (Jones, 2009), we focus in this section in applying recommendations specifically to the PBL environments.

Design of the Project

Although student choice in problem selection is not typically a consideration in PBL approaches (de Graaff & Kolmos, 2003; Hmelo-Silver, 2004), allowing students to choose their project topic, teammates, and advisor provided students with the opportunity to feel empowered, to build upon their existing individual interests, and to feel that their project was more useful to their long-term goals. From this perspective, allowing students these choices can provide motivating opportunities to them. But not all students were motivated by these choices. Some students did not have true choices because they could not find a project topic that related to their long-term career goals and interests or could not find an advisor that was appropriate. In these cases, although the instructor intended to design the PBL courses for key MUSIC model components, the students did not benefit from the design because the lack of true choices. As a result, these students never became fully engaged.

This finding demonstrates the complexity in trying to design interesting projects for students. In the real-world settings that capstone courses seek to model, engineers have little or no control over the projects they work on; therefore, relying heavily on student interest can work against the learning goals of the course. At the same time, the importance of usefulness and interest on students' motivation suggest that instructors should maximize these components when possible. One option might be to provide as many reasonable topics for projects as possible, depending on the number of students, groups, technical advisors, and industry partners. When providing a variety of topics is not practical, instructors should develop alternative strategies, such as: identifying project components that students can pursue even within an "uninteresting" project, helping students make connections between project goals and personal goals, and helping shape project deliverables and division of labor in ways that help each student engage in the dimensions of the work they find interesting.

Further, instructors should explicitly communicate the ways in which the project reflects real-world experiences. Students reported higher levels of motivation when they perceived the project as a realistic simulation of the real world, thus making those connections explicit may improve motivation for students who do not perceive the connections on their own. In many capstone courses, this connection comes through industry-sponsored projects (though students may still view industry projects in light of academic expectations; Dannels, 2003). In other instances, the PBL framework itself provides a venue for instructors to establish a professional, rather than an academic, relationship with students and move the course dynamic towards a workplace environment (Paretti, 2006, 2008). That is, the PBL environment enables faculty to move from delivering knowledge in a traditional teacher/student model to functioning as a project manager with an emphasis on mentoring that more resembles a professional engineering environment. In addition, even when it is difficult to replicate real-world conditions within a course, instructors can acknowledge the differences and provide rationales that help students understand the usefulness of the academic components.

Role of the Instructors and Advisors

Models of PBL facilitation and mentoring suggest a range of important strategies for facilitators, including overall goals and strategies to support student learning (Hmelo-Silver & Barrows, 2006), specific types of questions and statements (Hmelo-Silver & Barrows, 2008), and the use of role-modeling to support cross-disciplinary PBL work (Fruchter & Lewis, 2001, 2003). The findings in the present study extend these strategies by highlighting the ways that course instructors and technical advisors need to communicate effectively with the student groups to negotiate an approach to facilitating projects that both empowers students to work with a high level of self-direction and provides enough guidance to support their perceptions that they can be successful. As with the role of student choice in project selection, this emphasis on negotiating facilitator roles increases the power students have over their own learning, and thus, explicitly contributes to the goals of PBL. Notably, our findings suggest that this negotiation is one of the most difficult tasks for instructors and advisors to implement well in PBL courses: balancing students' needs for empowerment and self-direction with their need to be provided with the support necessary to be successful. Some groups of students in our study wanted more guidance (i.e., more "hands-on"), whereas others liked the "hands-off" approach because they felt empowered by their freedom, echoing and extending the student perceptions identified by Henry et al. (2012) in exploring PBL in a materials science course. The amount of help each group needed varied, but advisors need to understand what students prefer or expect, and then work with them to create an environment in which the students feel supported, even if that environment does not match the students' or advisor's preferences. Importantly, instructors and advisors do not necessarily need to "cater" to student expectations, but rather, they can communicate how they believe their approach supports students' success, while listening and responding to students' concerns in a caring manner. Instructors may also need to provide groups with strategies for managing their expectations and negotiating situations in which the advisors provide less guidance than desired (including alternative resources, strategies for locating information and making decisions, and contracts that can help state expectations and responsibilities). Effective communication can mitigate situations such as those documented in this study in which students avoided talking with their advisor for fear of confrontation or offensive feedback.

In addition, consistent with recommendations from Hmelo-Silver and Barrows (2006) on the need for facilitators to keep all students active in the learning process, our findings suggests that instructors also need to monitor group dynamics and help groups address content and motivation problems. Perhaps it would be helpful if students were provided with more explicit guidance about how to communicate to group members that their work is unacceptable. Such concerns can be difficult to address because they involve sensitive interpersonal communication and are linked to differences in personalities, academic goals, and priorities. Such facilitation extends beyond the types of in-meeting mentoring Hmelo-Silver (2004) describes and moves into components of team leadership, including conflict management and team motivation. When instructors recognize the challenges of collaborative work and the potential problems, they can be more prepared to provide students with the necessary tools and guidance.

Finally, for students who are disengaged because their career plans or goals do not create or inherently generate interest and value, instructors need to demonstrate how the learning outcomes are relevant to other careers that might be seen as useful to them. While the use of realistic ill-structured problems is a hallmark of PBL (Hmelo-Silver, 2004), the use of this approach for in-major courses such as the design courses studied here suggests a need to create environments in which not only the problem itself, but also the work environment, provides a strong connection to students' intended professional work. For example, capstone courses often require critical thinking, creativity, problem solving, teamwork, and communications, skills that are important in most professional contexts, and helping students link their PBL work to their career plans appears to be an important pedagogical component of PBL in this environment. Although such connections may not increase individual interest, they can increase usefulness, and coupled with empowerment, success, and caring, increased usefulness may help students engage more fully with the course material.

Conclusion

Many elements of PBL courses provided motivating opportunities for students. These motivating opportunities are important because they can affect students' perceptions of MUSIC model components either positively or negatively. The number and variety of motivating opportunities available in PBL courses can be a real asset to instructors in motivating students. When managed inappropriately, however, they can lead to students' frustration and a lack of motivation. We hope that the identification and examination of instructional elements and motivating opportunities discussed in this paper will help instructors and advisors think about how they can plan and implement effective PBL instruction.

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References

Ames, C. (1992). Classrooms: Goals, structures, and student motivation. *Journal of Educational Psychology, 84*, 261–71. http://dx.doi.org/10.1037/0022-0663.84.3.261

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice-Hall.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: Freeman.

Barron, B. J. S., Schwartz, D. L., Vye, N. J., Moore, A., Petrosino, A., Zech, L., & Bransford, J. D. (1998). Doing with understanding: Lessons from research on problem- and project-based learning. *The Journal of the Learning Sciences, 7*(3–4), 271–311.

Bédard, D., Lison, C., Dalle, D., Côté, D., & Boutin, N. (2012). Problem-based and project-based learning in engineering and medicine: Determinants of students' engagement and persistance. *Interdisciplinary Journal of Problem-based Learning, 6*(2), 7–30. http://dx.doi.org/10.7771/1541-5015.1355

Beddoes, K. D., Jesiek, B. K., & Borrego, M. (2010). Identifying opportunities for collaborations in international engineering education research on problem- and project-based learning. *Interdisciplinary Journal of Problem-based Learning, 4*(2), 7–34. http://dx.doi.org/10.7771/1541-5015.1142

Bergin, C., & Bergin, D. (2009). Attachment in the classroom. *Educational Psychology Review, 21*, 141–70. http://dx.doi.org/10.1007/s10648-009-9104-0

Bergin, D. A. (1999). Influences on classroom interest. *Educational Psychologist, 34*, 87–98. http://dx.doi.org/10.1207/s15326985ep3402_2

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palinscar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist, 26*(3–4), 369–98. http://dx.doi.org/10.1080/00461520.1991.9653139

Cirstea, M. (2003). Problem-based learning (PBL) in microelectronics. *International Journal of Engineering Education, 19*(5), 738–41.

Cline, M., & Powers, G. J. (1997). *Problem based learning via open ended projects in Carnegie Mellon University's chemical engineering undergraduate laboratory*. Frontiers in Education annual conference, Pittsburgh, PA.

Corbin, J. M., & Strauss, A. L. (2008). *Basics of qualitative research* (3rd ed.). Thousand Oaks, CA: Sage.

Covington, M. V. (1992). *Making the grade: A self-worth perspective on motivation and school reform*. New York: Cambridge University Press. http://dx.doi.org/10.1017/CBO9781139173582

Creswell, J., & Plano-Clark, V. (2011). *Designing and conducting mixed methods research* (2nd ed.). Thousand Oaks, CA: Sage.

Dannels, D. P. (2003). Teaching and learning design presentations in engineering: Contradictions between academic and workplace activity systems. *Journal of Business and Technical Communication, 17*(2), 139–69. http://dx.doi.org/10.1177/1050651902250946

Deci, E. L., & Ryan, R. M. (1991). A motivational approach to self: Integration in personality. In R. Dientsbier (Ed.), *Nebraska symposium on motivation: Vol. 38*. Lincoln, NE: University of Nebraska Press.

Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry, 11*(4), 227–68. http://dx.doi.org/10.1207/S15327965PLI1104_01

de Graaff, E., & Kolmos, A. (2003). Characteristics of problem-based learning. *International Journal of Engineering Education, 19*(5), 657–62.

de Graaff, E., Kolmos, A., & Fruchter, R. (2003). Guest Editorial. *International Journal of Engineering Education, 19*(5), 656.

De Volder, M., & Lens, W. (1982). Academic achievement and future time perspective as a cognitive-motivational concept. *Journal of Personality and Social Psychology, 42*(3), 566–71. http://dx.doi.org/10.1037/0022-3514.42.3.566

Dunlap, J. C. (2006). The effect of a problem-centered, enculturating experience on doctoral students' self-efficacy. *Interdisciplinary Journal of Problem-based Learning, 1*(2), 19–48. http://dx.doi.org/10.7771/1541-5015.1025

Dutson, A. J., Todd, R. H., Magleby, S. P., & Sorensen, C. D. (1997). A review of literature on teaching engineering design through project-oriented capstone courses. *Journal of Engineering Education, 86*(1), 17–28. http://dx.doi.org/10.1002/j.2168-9830.1997.tb00260.x

Evans, M. A., Jones, B. D., & Akalin, S. (2012, April). *Leveraging digital game design in an informal science learning environment to motivate high school students in biology*. Paper presented at the annual meeting of the American Educational Research Association, Vancouver, Canada.

Fink, F. K. (1999, November). *Integration of engineering practice into curriculum—25 years of experience with problem based learning.* Paper presented at the ASEE/IEEE Frontiers in Education, San Juan, Puerto Rico.

Fruchter, R., & Lewis, S. (2001). *Mentoring models in an A/E/C global teamwork e-learning environment.* Paper presented at the American Society for Engineering Education Annual Conference and Exposition.

Fruchter, R., & Lewis, S. (2003). Mentoring models in support of P5BL in architecture/engineering/construction global teamwork. *International Journal of Engineering Education, 19*(5), 663–71.

Ge, X., Huang, K., & Dong, Y. (2010). An investigation of an open-source software development environment in a software engineering graduate course. *Interdisciplinary Journal of Problem-based Learning, 4*(2), 94–120. http://dx.doi.org/10.7771/1541-5015.1120

Henry, H. R., Tawfik, A. A., Jonassen, D. H., Winholtz, R. A., & Khanna, S. (2012). "I know this is supposed to be more like the real world, but . . .": Student perceptions of a PBL implementation in an undergraduate materials science course. *Interdisciplinary Journal of Problem-based Learning, 6*(1), 43–81. http://dx.doi.org/10.7771/1541-5015.1312

Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist, 41*(2), 111–27. http://dx.doi.org/10.1207/s15326985ep4102_4

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review, 16*(3), 235–66. http://dx.doi.org/10.1023/B:EDPR.0000034022.16470.f3

Hmelo-Silver, C., & Barrows, H. (2006). Goals and strategies of a problem-based learning facilitator. *Interdisciplinary Journal of Problem-based Learning, 1*(1), 23–39. http://dx.doi.org/10.7771/1541-5015.1004

Hmelo-Silver, C., & Barrows, H. (2008). Facilitating collaborative knowledge building. *Cognition and Instruction, 26*(1), 48–94. http://dx.doi.org/10.1080/07370000701798495

Hong, J. C. (2007). *The comparison of problem-based learning (PmBL) model and project-based learning (PtBL) model.* International Conference on Engineering Education (ICEE) 2007, Coibra, Portugal.

Howe, S. (2010). Where are we now? Statistics on capstone courses nationwide. *Advances in Engineering Education, 2*(1), 1–27.

Hulleman, C. S., Durik, A. M., Schweigert, S. A., & Harackiewicz, J. M. (2008). Task values, achievement goals, and interest: An integrative analysis. *Journal of Educational Psychology, 100*(2), 398–416. http://dx.doi.org/10.1037/0022-0663.100.2.398

Ivankova, N. V., Creswell, J. W., & Stick, S. L. (2006). Using mixed-methods sequential explanatory design: From theory to practice. *Field Methods, 18*(1), 3–20. http://dx.doi.org/10.1177/1525822X05282260

Jesiek, B. K., & Strobel, J. (2010). Guest editor's introduction. *Interdisciplinary Journal of Problem-based Learning, 4*(2), 4–6. http://dx.doi.org/10.7771/1541-5015.1179

Johnson, D. W., Johnson, R., & Anderson, A. (1983). Social interdependence and classroom climate. *Journal of Psychology, 114*(1), 135–42. http://dx.doi.org/10.1080/00223980.1983.9915406

Jones, B. D. (2009). Motivating students to engage in learning: The MUSIC Model of Academic Motivation. *International Journal of Teaching and Learning in Higher Education, 21*(3), 272–85.

Jones, B. D. (2010a). An examination of motivation model components in face-to-face and online instruction. *Electronic Journal of Research in Educational Psychology, 8*(3), 915–44.

Jones, B. D. (2010b, October). *Strategies to implement a motivation model and increase student engagement*. Paper presented at the annual meeting of the International Society for Exploring Teaching and Learning, Nashville, TN. Retrieved from http://www.MotivatingStudents.info

Jones, B. D., Ruff, C., Snyder, J. D., Petrich, B., & Koonce, C. (2012). The effects of mind mapping activities on students' motivation. *International Journal for the Scholarship of Teaching and Learning, 6*(1), 1–21.

Jones, B. D., & Skaggs, G. (2012, August). *Validation of the MUSIC Model of Academic Motivation Inventory: A measure of students' motivation in college courses*. Research presented at the International Conference on Motivation 2012. Frankfurt, Germany.

Jones, B. D., Watson, J. M., Rakes, L., & Akalin, S. (2012). Factors that impact students' motivation in an online course: Using the MUSIC Model of Academic Motivation. *Journal of Teaching and Learning with Technology, 1*(1), 42–58

Jones, B. D., & Wilkins, J. L. M. (in press). Testing the MUSIC Model of Academic Motivation through confirmatory factor analysis. *Educational Psychology*. doi:10.1080/01443410.2013.785044

Kauffman, D. F., & Husman, J. (2004). Effects of time perspective on student motivation: Introduction to a special issue. *Educational Psychology Review, 16*(1), 1–7. http://dx.doi.org/10.1023/B:EDPR.0000012342.37854.58

Knight, D. W., Carlson, L. E., & Sullivan, J. (2007, June). *Improving engineering student retention through hands-on, team based, first-year design projects.* Paper presented at the International Conference on Research in Engineering Education, Honolulu.

LaPlaca, M. C., Newstetter, W. C., & Yoganathan, A. P. (2001, October). *Problem-based learning in biomedical engineering curricula*. ASEE/IEEE Frontiers in Education annual conference, Reno, NV.

Marsh, H. W. (1990). A multidimensional, hierarchical self-concept: Theoretical and empirical justification. *Educational Psychology Review, 2*, 77–172.

Matusovich, H., Jones, B. D., Paretti, M., Moore, J., & Hunter, D. (2011, June). *Motivating factors in problem-based learning: A student perspective on the role of the facilitator.* Paper presented at the annual meeting of the American Society for Engineering Education, Vancouver, Canada.

McIntyre, C. (2002). *Problem-based learning as applied to the construction and engineering capstone course at North Dakota State University*. ASEE/IEEE Frontiers in Education annual conference, Boston, MA.

McKenzie, L. J., Trevisan, M. S., Davis, D. C., & Beyerlein, S. W. (2004, June). *Capstone design courses and assessment: A national study*. American Society for Engineering Education Annual Conference and Exposition, Salt Lake City.

Mgangira, M. B. (2003). Integrating the development of employability skills into a civil engineering core subject through a problem-based learning approach. *International Journal of Engineering Education, 19*(5), 759–61.

Noddings, N. (1992). *The challenge to care in schools : An alternative approach to education.* New York: Teachers College Press.

Paretti, M. C. (2006). Audience awareness: Leveraging problem-based learning to teach workplace communication practice. *IEEE Transactions on Professional Communication, 49*(6), 189–98. http://dx.doi.org/10.1109/TPC.2006.875083

Paretti, M. C. (2008). Teaching communication in capstone design: The role of the instructor in situated learning. *Journal of Engineering Education, 97*(4), 491–503. http://dx.doi.org/10.1002/j.2168-9830.2008.tb00995.x

Patton, M. Q. (2002). *Qualitative Research and Evaluation Methods (3rd ed.).* Thousand Oaks, CA: Sage.

Pembridge, J. J., & Paretti, M. C. (2010, June). *The current state of capstone design pedagogy.* Paper presented at the American Society in Engineering Education Annual Conference and Exhibition, Louisville, KY.

Pierrakos, O., Zilberberg, A., & Anderson, R. (2010). Understanding undergraduate research experiences through the lens of problem-based learning: Implications for curriculum translation. *Interdisciplinary Journal of Problem-based Learning, 4*(2), 35–62. http://dx.doi.org/10.7771/1541-5015.1103

Savery, J. R. (2006). Overview of problem-based learning: Definitions and distinctions. *Interdisciplinary Journal of Problem-based Learning, 1*(1), 9–20. http://dx.doi.org/10.7771/1541-5015.1002

Schmader, T., Major, B., & Gramzow, R. H. (2001). Coping with ethnic stereotypes in the academic domain: Perceived injustice and psychological disengagement. *Journal of Social Issues, 57*(1), 93–111. http://dx.doi.org/10.1111/0022-4537.00203

Schunk, D. H., Pintrich, P. R., & Meece, J. L. (2008). *Motivation in education: Theory, research, and applications*. Upper Saddle River, NJ: Pearson.

Sheppard, S. D., Macatangay, K., Colby, A., Sullivan, W. M., & Shulman, L. S. (2008). *Educating engineers: Designing for the future of the field*. Hoboken, NJ: Jossey-Bass.

Simpkins, S. D., Davis-Kean, P. E., & Eccles, J. S. (2006). Math and science motivation: A longitudinal examination of the links between choices and beliefs. *Developmental Psychology, 42*(1), 70–83. http://dx.doi.org/10.1037/0012-1649.42.1.70

Striegel, A., & Rover, D. T. (2002). *Problem-based learning in an introductory computer-engineering course.* Paper presented at the ASEE/IEEE Frontiers in Education Conference, Boston, MA.

Todd, R. H., Magleby, S. P., Sorensen, C. D., Swan, B. R., & Anthony, D. K. (1995). A survey of capstone engineering courses in North American. *Journal of Engineering Education, 84*(2), 165–74. http://dx.doi.org/10.1002/j.2168-9830.1995.tb00163.x

Wigfield, A., & Eccles, J. S. (2000). Expectancy-value theory of achievement motivation. *Contemporary Educational Psychology, 25*, 68–81. http://dx.doi.org/10.1006/ceps.1999.1015

Williams, G. C., & Deci, E. L. (1996). Internalization of biopsychosocial values by medical students: A test of self-determination theory. *Journal of Personality and Social Psychology, 70*(4), 767–79. http://dx.doi.org/10.1037/0022-3514.70.4.767

Williams, G. C., Freedman, Z. R., & Deci, E. L. (1998). Supporting autonomy to motivate glucose control in patients with diabetes. *Diabetes Care, 21*(10), 1644–51. http://dx.doi.org/10.2337/diacare.21.10.1644

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Appendix

Interview Protocol

eMpowerment

- As you worked on your project, what aspects of the project were you able to control?
- What types of decisions did your group make in regards to how your group functioned?
- What was the result of those decisions?
- What types of decisions did your advisor make for you?

Usefulness

- How will what you are learning in this group project be useful to your short-term goals? Long-term goals?
- Was working within a collaborative group a realistic simulation of a real-world work experience? Please describe.

Success

- What aspects of this project make you feel competent? Overwhelmed? Bored?
- Describe the feedback you have received from the instructor and your advisor on this project.
- How does that differ from the feedback you received from your group members?
- What feedback has contributed most to your success?
- Do you believe that working within a group made this project easier or more challenging? Please explain.

Interest

- How did your group determine the topic you selected?
- Describe your initial interest in the project.
- How did working in a group influence your interest in the project?
- Describe your interest in the project now.
- Has this changed? If yes, what caused the change?
- Are the ideas and/or topics in this project really important to you? Please explain what makes them important to you.
- That is, do you care about the ideas, issues, and/or topics involved in this project?

Caring

- Describe your group's dynamics.
- Describe how you interacted with your group members.

- What would you change about the dynamics of your group?
- Describe your group's relationship with your advisor.
- What role did your project's advisor play?
- How does your advisor show respect and concern for your group?
- What would you change about the role of your advisor?