Beginning to Understand Variation in Teaching Approaches to Game-Based Learning

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Abstract— **Recently, games have grown in popularity as tools to support student learning and motivation. Accordingly, games represent one possible contributor to student motivation, an outcome of engineering education particularly important to learning and to student persistence. However, research into game-based learning—a broad term referring to the use of games in education—has been rather narrow to date, focusing on proving or disproving the effectiveness of games as learning tools. As evidence supporting games' effectiveness continues to mount, it is important that the field broaden its inquiry to provide practice-based insights that enable instructors to implement game-based learning in an effective manner. Our research seeks to address this gap by studying how engineering instructors use games in the classroom, and how these teaching practices related to student motivation to learn. The overall study will use a multiple-case study approach, including observations and interviews with instructors and their students. Preliminary results from this work-in-progress study revealed substantial variability in the teaching practices of two engineering instructors using non-digital games, and provided several methodological implications for future study of game-based teaching.**

Keywords—game-based learning; pedagogy; instruction; qualitative research

I. Introduction

Over the past decade, games have grown in popularity as tools to support student learning and motivation. Within engineering education in particular, Bodnar and her colleagues recently captured an increasing trend in research reporting on the use of games to help teach engineering content [1]. Given the strong theoretical foundation of games for supporting player motivation [2-4], use of games in engineering classrooms represents one possible contributor to student motivation, an outcome of engineering education particularly important to learning and student persistence [5-7].

However, research into game-based learning (GBL)—a broad term referring to the use of games in education—has been rather narrow to date, focusing on proving or disproving the effectiveness of games as tools for learning [8, 9]. As recent meta-analyses and systematic reviews have summarized, this research has produced fruitful results by providing evidence that GBL tends to result in positive effects on learning outcomes [1, 10]. On the other hand, researchers have given little attention to at least two other lines of research that will be important to consider as GBL proliferates as a pedagogy.

First, GBL researchers have given less consideration to the relationship between GBL and student motivation, especially in classroom contexts. Contemporary GBL literature has established a strong theoretical basis for why games are motivating [2-4], linking games to established psychological theories of motivation such as intrinsic motivation from self-determination theory [11], interest theory [12], and achievement goal theory [13]. However, empirical studies on the effects of games on motivation using these theories are rarer, and tend to inquire about the aspects of game design that motivate players to stay engaged with gameplay [2, 3]. Very few studies have attempted to empirically evaluate how GBL affects student's motivation-related beliefs and values about the curricular content a game is intended to address [3], which decades of research has demonstrated to be crucial in supporting student learning, transfer, and long-term persistence [5-7]. Accordingly, future research should prioritize studying how GBL affects students' motivation to remain engaged with the content being learned, not just the game being played.

Second, GBL research tends to relegate pedagogical aspects of GBL—i.e., the teaching practices through which instructors actually implement GBL in their classrooms—as secondary considerations compared to the game's design [8, 9]. Relegating game-based teaching practices as secondary is problematic not only because it ignores potentially important contributors to the effectiveness of GBL, but also because it limits researchers' ability to provide concrete recommendations for efficacious GBL practice to instructors. As evidence supporting games' effectiveness continues to mount, it is important that the field of GBL broaden its inquiry to provide insights that will enable instructors and educational policymakers to implement game-based learning in an effective manner. Studying how instructors use games in their classrooms is one way of providing such insights.

This paper presents results from a pilot study for a qualitative research project that aims to address both game-based teaching practices in engineering education and their relationship to student motivation to learn. The overarching research project will involve conducting observations of both digital and non-digital game-based learning activities, as well as interviews with teachers and students involved in the activities. In doing so, we intend to eventually answer the following research question: What is the role of student

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motivation in (1) instructor beliefs that influence the design of digital and non-digital game-based learning activities, and (2) student perceptions of these activities?

The purpose of this pilot study was to begin to understand how game-based teaching practices vary across engineering instructors. Accordingly, we observed game-based learning activities conducted by two engineering instructors at different institutions to answer the following sub-question: *What commonalities and differences existed in the game-based teaching approaches used by the two instructors?* The process of answering this question elucidated several insights that will contribute to the overarching research project, including aspects of game-based teaching that may be particularly important to capture in future data collection and other methodological considerations for observing game-based learning activities. Given that game-based teaching is a rarely studied phenomenon in GBL research—and perhaps not studied at all in engineering education—insights from this pilot study represent a step forward in cataloging game-based teaching practices to provide useful practice recommendations for engineering instructors interested in using games.

II. Overarching Research Project

To characterize the relationship between game-based teaching practices and student motivation, we will use a qualitative, multiple-case study approach involving interviews and observations in three digital game-based teaching cases and three non-digital game-based teaching cases. In each case, we will interview instructors to determine how their beliefs about student motivation shape how they plan game-based learning activities, and we will interview students to assess how the instructor's game-based teaching practices are perceived by students with respect to impact on motivation.

The conceptual framework for the study is the MUSIC Model of Academic Motivation [14]. The MUSIC Model compiles findings from psychological theories of student motivation to posit that motivation to learn can be supported by addressing five components:

- eMpowerment: The extent to which students believe they have meaningful control over their learning.
- Usefulness: The extent to which students believe the learning content will be useful to them.
- Success: The extent to which students believe that they can be successful if they put effort into a learning activity.
- Interest: The extent to which students find learning activities interesting and enjoyable.
- Caring: The extent to which students believe the instructor cares about their success and well-being.

The contributions of the MUSIC Model components to student motivation have been well-documented by several theories of motivation [14]. The MUSIC Model itself has seen several applications in engineering education, many of which have emphasized the importance of faculty and instructor practices in influencing MUSIC components [15-17]. Using the MUSIC Model for this research project will allow us to empirically connect game-based teaching practices to a large body of psychological research on student motivation using a model that is well-suited for the study of instructor pedagogy.

III. Pilot Study: Game-Based Teaching Observations

To better inform the methodology of the overarching research project, we conducted observations of non-digital game-based learning activities created and used by two engineering instructors at different institutions. For each instructor, we observed one class period, during which multiple game-based activities took place. The contexts of the instructors' courses substantially differed from one another, as did the types of game-based activities they employed.

The first instructor, Trevor (pseudonym), was an associate professor at a small, private, teaching-focused university in the eastern United States. In the one-hour class session we observed, Trevor taught a senior-level, project-based course with a cohort of approximately 15 students he had taught in several previous courses. During the class session, Trevor conducted five short game-based activities that involved physical activity (body movement) and interactions between students. For example, one activity asked students, to "sculpt" their body postures to attempt to communicate an intangible concept. The activities were intended to connect to an overarching discussion on engineering communication and teamwork, and the takeaways from the activities were heavily interconnected.

The second instructor, Bethany (pseudonym), was an assistant professor at a medium-sized, public, research-focused university in the eastern United States. The class session we observed was a sophomore-level, three-hour lab course in which the first 90 minutes of that particular session were used for game-based activities. There were approximately 20 students in the class, and Bethany had not taught any students in the course in prior academic terms. During the class session, Bethany conducted two game-based activities which substantially differed from one another. The first activity was a class-wide cooperative game in which students had to communicate symbolic (pictorial) information to one another orally in an attempt to decipher symbolic codes. The second activity was a team-based, competitive game in which student teams tried to craft a presentation slide of high enough quality that it convinced other teams that the slide was made by a professional engineer. Bethany intended both her games to address technical communication skills in engineering.

During each instructor's class session, we observed and video-recorded game-based activities. We took notes on the instructor's actions before, during, and after gameplay, as well as any student actions that led to instructor-student interactions. We also prepared a more structured observation protocol using the Observation Protocol for Adaptive Learning (OPAL) [18], but found that activities progressed too quickly to devote enough attention to the protocol on-site. Instead, the protocol became the basis for analyzing the observation data. Following observations, we met with each instructor briefly to ask a series of follow-up questions. These questions ranged in purpose, including clarifications about instructor actions, questions about student behavior more generally, or inquiries about the instructor's reasoning for particular practices.

We analyzed the data in accordance OPAL. OPAL was designed to dissect active learning activities into nine discretely observable dimensions [18], many of which are grounded in psychological theories of student motivation:

1. The structure of the task students are asked to complete
2. The existing authority structure and rules within the classroom
3. The degree of autonomy students have over the activity
4. The kinds of recognition, praise, and criticism students receive from the instructor
5. How the grouping of students is performed
6. The kinds of evaluation students perform or receive on their work in the activity
7. The time schedule or restrictions of the activity
8. The kinds of social interactions that the instructor encourages or discourages
9. How students go about help-seeking during the activity

We organized our preliminary results around six of these nine variables. Because our focus was on teacher practices during the observed session and because the video recordings did not appropriately capture teacher-student conversations during the activity, dimensions 2, 4, and 9 are not represented in our findings.

IV. Preliminary Findings

Table 1 displays which OPAL dimensions revealed similarities and/or differences across instructors' teaching practices. The context of each similarity and difference suggests which aspects of game-based activities should be highlighted in future work observing game-based teaching practices. Thus, findings related to each OPAL dimension deserve more detailed examination.

A. Task Structure

Both Trevor and Bethany structured their class sessions around multiple game-based activities, each followed by a short debriefing discussion to help students connect the activities to engineering-relevant learning outcomes. Debriefing across Trevor's five activities tended to be cumulative, with takeaways from each activity building upon the takeaways from previous activities. Debriefing for Bethany's two activities was more standalone, with each activity connecting to distinct takeaways. Each instructor allowed different levels of student autonomy for debriefing discussions.

TABLE I. Similarities and Differences in Teaching Practices Across Instructors

OPAL Dimension	Similarities Across Instructors	Differences Between Instructors
1. Task Structure	X	X
3. Student Autonomy		X
5. Student Grouping	X	
6. Student Evaluation	X	
7. Use of Time	X	X
8. Social Interactions		X

Trevor and Bethany differed regarding how they oriented students to the purpose, rules, and instructions of each game-based activity. Bethany took a proactive approach to orientation of her two activities, telling students all the rules of the games upfront and priming them regarding the activities' relationships to engineering communication prior to gameplay. Trevor, on the other hand, was more active in giving instructions during the activities, providing students with one direction at a time. Although Trevor started the class session by explicating the importance of play to learning, he did not prime students about the engineering value of the games prior to play. Each of these approaches to orientation led to differences in levels of student autonomy.

B. Student Autonomy

Each instructor gave students more autonomy over different aspects of the game-based activities. Trevor, with his step-by-step directions, offered less autonomy to students during activities. While one activity gave students more freedom to solve an open-ended problem (the body "sculpting" game described earlier), most of the challenge in Trevor's games came from attempting to respond to the instructions as well as possible. On the other hand, Trevor gave students more autonomy during debriefing, as he encouraged students to discuss the meaning they each took from the activity before offering more discipline-specific takeaways. The open-endedness of this debriefing process was supported by the fact that Trevor did not prime students regarding each game's purpose upfront.

Bethany's strategy of giving students all the game's rules upfront led to greater student autonomy during gameplay. Students worked toward solving open-ended problems posed by each game's ruleset and objectives, rather than responding incremental micro-challenges like in Trevor's games. During debriefing, Bethany's students had less autonomy. Bethany had a clear list of takeaways for each activity, and even prepared some slides for the debriefing discussions. Students were still encouraged to suggest their own takeaways, but Bethany was careful to connect student responses to the predetermined learning objectives.

C. Student Grouping

With the exception of two games (one from each instructor), which involved cooperation among the entire class, all the games involved students working in groups. In each case, Bethany and Trevor defined appropriate group sizes, and students were allowed to group themselves as they saw fit.

D. Student Evaluation

All of the games used by Trevor and Bethany had built-in means for students to know how well they did in the game. For Trevor's games, in Trevor's body "sculpting" game, students knew how effective their "sculptures" were based on how well other students were able to guess the concept they were trying to communicate. As another example, in Bethany's symbolic deciphering game, students entered the messages they decoded into an online platform her game designer partner created that told students whether or not they correctly deciphered their symbols. Thus, students in each game received near-instant feedback on how well they did, sometimes from the instructor and sometimes from other students.

In no case did student performance in the game translate to any real-world consequence, such as grade assignment. Neither Bethany nor Trevor were interested in using their games to summatively assess student achievement of the learning objectives. Rather, the games were tools to engage students in learning professional engineering skills, and both instructors seemed to consider the debriefing sessions after each game as sufficient to formatively assess student takeaways from gameplay activities.

E. *Use of Time*

Trevor and Bethany both played an active role in using and managing the amount of time devoted to each game activity. Particularly, both adjusted the length of gameplay and debriefing sessions based on their assessment of student engagement and progress. Trevor, for example, had originally planned to do six activities, but decided to instead devote more time to five activities as he noticed that students found more debriefing time valuable for each. Similarly, Bethany had originally planned to devote equal time to her two games, but decided to spend more time on the first game (the symbolic deciphering game) when her students protested the idea of cutting off the first game before all the messages had been deciphered.

However, Trevor and Bethany took different approaches to using time to support gameplay. Trevor rarely gave students a time limit, but rather provided new instructions at time intervals he felt were appropriate. For example, in the body "sculpting" game, he would say "Okay, it's time to start putting your sculptures together," rather than "you have three minutes left to finish your sculptures." On the other hand, Bethany continually gave students time limits, but intentionally did not enforce them. For example, she started the symbolic deciphering game by announcing that students had 10 minutes to decipher all messages, but actually gave students approximately 20 minutes to complete the activity. When asked about this after the game, she responded, "Time is fluid in games," and stated that having shorter perceptions of time limits helped keep pressure on students to keep them engaged.

F. *Social Interactions*

While students in both instructors' games engaged in substantial social interaction, the way students interacted with one another depended heavily on the materials used for each game. Trevor used no physical materials in his games, and students interacted with one another primarily by manipulating one another's bodies. In the body "sculpting" game, for example, students orally communicated to decide how each person's body needed to be positioned to best communicate their target concept. Bethany, on the other hand, used several physical materials. In the symbolic deciphering game, symbols and their meanings were scattered across private cards that were distributed among students. Thus, most of the game's interactions involved students frantically seeking out other students who had the cards with the information they needed to decode their own symbols. Bethany's other game required extensive use of slideshow software, and so most interactions took place in small groups around computers.

V. Brief Discussion & Future Work

The pilot data presented in this paper revealed that although several aspects of game-based teaching may be shared across instructors, there is also substantial variability in how instructors teach using non-digital games. Particularly, we found that the two participant instructors varied in how they oriented students to their games, the amount of autonomy they allowed students during gameplay and debriefing, how they used and managed time during activities, and their use of physical materials to facilitate particular kinds of student interaction. Our findings provide preliminary evidence for the importance of studying game-based teaching practices in greater detail than in current literature. To date, the modicum of research on game-based teaching practices has focused on models of teacher roles related to gameplay [9, 19] or phases of game-based learning activities [20, 21]. While these models are useful for beginning to understand teacher practices, they omit many of the details of game-based teaching that are captured by a protocol like OPAL. These details may have important implications for support of student outcomes such as motivation to learn.

The next step in this research project is to more thoroughly catalog variance in the game-based teaching practices of engineering instructors, and to understand how these varied teaching practices relate to student motivation to learn in both digital and non-digital game-based learning activities. For example, differences in student autonomy during gameplay and debriefing may lead to differences in student perceptions of their degree of empowerment and of the usefulness of the activity to their goals, both of which would affect student motivation to learn according to the MUSIC Model. Our follow-up study of the relationship between game-based teaching practices and student motivation will employ not only observations like those in the pilot study, but also interview data from both instructors and students. This pilot study revealed at least three methodological implications for instructor data collection. First, OPAL is a suitable observation protocol for this research, but is better applied during data analysis than data collection. Second, data collection should focus on capturing high-quality video and audio recordings for later reference, especially in terms of better recording instructor-student dialogue. Third, a follow-up interview after observation is necessary to develop a complete understanding of game-based teaching.

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