Workshop: Taking it to the Next Level...Game-Based Learning in Engineering Education

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Games and gamification implementations can be very powerful experiential learning opportunities for students that connect their time in play back to course material. The use of games within engineering classes has steadily increased, as evidenced by increasing numbers of publications on their implementation and effectiveness [1]. Games within engineering classes can include classroom games (board, card, and live action), digital games, and gamification elements. However, there are still many faculty that aren't aware of this pedagogy. This workshop paper will provide an overview of what defines a game, how has game-based learning been applied within engineering and the process for connecting these "play" experiences back to technical content.

What Constitutes a Game?

A game is defined as a structured form of play where participants must accomplish a goal while adhering to specific rules [2]. Games are inherently engaging and immersive, foster teamwork, and provide immediate feedback to players, promoting experimentation and creative problem solving [3], [4] many of which are key skill sets that professional engineers possess.

Games can take several forms within a classroom. One of the most common means to implement a game is a classroom game, such as a card game, board game, or live-action game that promotes communication, comprehension, or critical thinking about class material. Alternatively digital games can be used where students play a specifically-designed game or simulation with certain constraints, allowing students to practice skills or make choices in a safe, risk-free environment.

Another increasingly common means of implementing games is called gamification, or the application of game elements to non-game scenarios [5]. In gamified classrooms, game elements are an integral element of the class experience. Classroom gamification often uses badges, points, and leaderboards (BPL) to track student progress and achievement in a course. While BPL can be a good introduction to gamification, studies have shown that adding meaningful game elements, such as narrative, conflict, and choice, can sustain student engagement with a gamified course [6], [7].

Game-Based Learning in Engineering Education

Bodnar and colleagues [1] conducted a systematic review of game-based learning within engineering. Through an inclusion/exclusion filtering process, 191 studies were included in the primary review set, of which 62 included studies on learning outcomes [1]. The review demonstrated games have been used in a variety of engineering disciplines ranging from first-year programs to core disciplines to specific topics within engineering such as ethics and design. However, the most frequent published use of games was in computer, mechanical, electrical, and first-year engineering disciplines. There was also a diversity of the types of games being used in engineering classrooms, including gamification methods, board/card games, and digital implementations, with the latter being the most prevalent [1]. The results suggested there is general consensus that student learning and attitudes improve with game-based activities.

However, additional research needs to be done in the engineering education community to explore game-based learning strategies and continue to evaluate their effectiveness.

Three examples of game approaches in engineering education include one-off games, badges/points/leaderboard examples, and the introduction of narrative elements into the class.

One-Off Games: One-off games are completed in a single sitting. They generally are easy to set up, explain, play, and debrief in a constrained time frame. Many faculty may already use one-off games without realizing it - for example, a Jeopardy-type game as a review session. These can be established games introduced to accomplish a certain task, such as a review, or they can be developed to tackle a certain topic. As an example, one of the authors developed a Cards Against Humanity style prompt-response game with the theme of engineering ethics [8].

Badges/Points/Leaderboards: The BPL approach can be used to incentivize students to learn required material or perform optional, extra tasks. Many examples of BPL approaches exist in the literature, and some examples are evident in mainstream culture, such as Weight Watchers (stay within your point limit; compete with friends). Designing a class around *competencies* (i.e. public speaking, projects, ethical reasoning) can lend itself to a BPL approach. *Groups* of students (i.e. laboratories, design classes) are also potential targets for BPL, as they often include collaborative and competitive aspects.

Narrative Games: Narrative games are where the class, or portions of it, have a story arc. That arc may be an entire semester/class or a subset of the class within a set time period. The story theme and how class elements interact with it help give it structure and rules, and allow students to understand connections. Themes can be serious (i.e. technical simulations, real-world scenarios) or more whimsical (i.e. fantasy, fiction). The story serves to anchor the students and provide opportunities for engagement with the material, and students' collective actions can drive and influence the story driving engagement.

Approaches to Game Facilitation and Debriefing

Active and passive facilitation can both be applied in game-based implementations. In active facilitation, the instructor serves as the lead for setting the context of the game play, defining the objectives and providing the rules to be adhered to in order to reach the end goal. In this type of role, the instructor needs to be clear and concise so that the individuals playing the game can fully understand what they are being asked to accomplish. In contrast, passive facilitation can be done when the type of game-based learning activity doesn't require specific introduction. Two examples of this form of facilitation would include a digital based game where the story, rules and goal are explicitly built into the game itself or a game-based circuit where different class based games are used and the instructions for each game are provided beside the activity so no direct introduction is necessary [9].

Regardless of the choice of facilitation method, there are some key best practices that instructors should keep in mind when integrating game-based learning. (1) Game play should last only as long as all students are engaged. This means trying to achieve the correct balance between fun and learning [10] (2) Players should be given the option to choose how they participate or they should be challenged by choice [11]. This means that observing game play is just as relevant as

actually participating in the game experience itself. (3) It is important to understand your audience. Selecting the game-based activity that best accomplishes your learning goals should go hand in hand with an activity that aligns with the interests of the participants. For instance, certain individuals do not engage well with competitive type games. In this case, use of a cooperative game would be better suited for the class environment [9].

Debriefing is a vital aspect of game-based learning strategies as it provides feedback to help learners reflect on their experience and understand how games can improve overall instructional effectiveness [12]. Hays describes three phases of debriefing including self-reflection about the game experience, guided reflection on their individual experiences and personal meanings, and discussion on the broader applications. The result of the debriefing process is that learners discover meaningful connections between the activity and their own lives, thus increasing the learning that occurs [13]. Kolb describes the learning process as one where knowledge is created through a transformation of experience where learners first have a concrete experience, reflect on that experience, relate the concepts in the experience to previously learned concepts, and make connections of the experience to the real world [14]. There are a number of approaches to debriefing that have been used throughout the years. Some have argued that a scaffolded facilitated approach to debriefing is required, where reflection facilitation starts on the lowest level of Bloom's taxonomy and progresses upwards as students begin to make meaning of the experience [15]; others have used self-assessment tools although with mixed results [16]. Regardless of the approach chosen, the debriefing activity should allow for the learner to mentally shift from doing to reflecting.

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