CURIOUS CONVERSATIONS: USING GAME-BASED LEARNING TO DEVELOP CREATIVE CULTURE WITHIN TECHNICAL COURSES

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Engineering products and solutions have revolutionized daily living, resulting in longer and more productive activities. However, the continued development of electronic components will be hindered as their sizes are reaching quantum levels. Creative engineers are needed to find solutions to this problem so that innovation in technology can be sustained. In this paper, we suggest that technical engineering courses can support developing creative culture by using game-based learning. Specifically, engineering students can design their own games as a pedagogical approach to develop creativity, learn innovation, and increase their technical learning outcomes. We illustrate this suggestion using examples from senior electrical engineering technical content.

INTRODUCTION

Engineers face many challenges that require innovation and entrepreneurship (Mann, 2000; Nassif et al, 2010). Today's industry leaders, especially high-tech companies such as Intel, Google, and Microsoft, are continually looking for engineers to design innovative technologies, and are investing their own efforts and resources into education (Intel, 2012; University of Calgary, 2013). In postsecondary education, a common teaching and learning model used is Bloom's Taxonomy, which consists of three separate domains- cognitive, affective, and psychomotor. Engineering education focuses on the development of the cognitive domain: remembering, understanding, applying, analyzing, evaluating, and finally creating. Technical courses place emphasis on the earlier stages where students are taught and assessed on remembering and understanding concepts. However, studies have shown that most learning happens in the latter stages, when students have a chance to analyze and create (Robinson, 2009).

Creativity is essential to innovative design, and is a crucial ability for engineers to exhibit (Daly, 2014; Felder, 1987; Felder, 1988). At the same time, the Canadian Engineering Graduate Attributes outlined by the Canadian Engineering Accreditation Board include creativity within design skills, multidisciplinary teamwork experience, and problem analysis, as well as a knowledge base for engineering (CEAB, 2012). This ability leads to new and useful products, processes, tools, and techniques for improving our lives, and allows engineering firms to remain sustainable and competitive on the global scale (Daly, 2014; Robinson, 2009). While there are some design courses within an engineering program that provide opportunities for creative development, most engineering curricula are focused on technical learning outcomes.

Past studies have shown that while engineering instructors value creativity, they believe it to be lacking in their students. At the same time, engineering students do not think that creativity is valued by their professors (Daly, 2014). While there is a greater industry emphasis

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on recruiting creative engineers and a greater interest in creativity from new engineering students, related literature questions if postsecondary institutions are teaching creative thinking to their engineering students (Daly, 2014; Liu, 2004). Past work has also shown that students in technical fields, such as science, engineering or mathematics, do not view themselves as being creative and may also have misconceptions regarding a lack of creativity in their field (Marasco, 2015). We suggest that it is time for technical engineering courses to combine developing a creative culture of future engineers with technical skills development. This paper proposes gamification and learner-generated game-based learning pedagogical techniques for teaching creative thinking and improving creative confidence, while adding value to technical learning outcomes. Elements of design, art, and entrepreneurship are combined in a cross-disciplinary approach for generating conversation around creative thinking and application of technical domain concepts in problem-solving.

GAME-BASED TEACHING AND LEARNING

We are turning our attention to the potential of games in engineering education, considering that games are models of systems (Gee, 2008; Zimmerman, 2013). Algorithms and rules underlie the games, like any engineered products. Games have been applied in learning contexts by defining and/or aligning learning outcomes with game goals (Shaffer et al., 2005). Another trend in engineering education is gamification, which is to use game-like mechanics in behavioral aspects of learning (e.g., finishing multiple tasks within the deadlines) to motivate learners (e.g., Tolman et al, 2015; Kuo & Chuang, 2016). Our approach considers the power of learner-generated designs in learning (Kim et al, 2015), and moves beyond the motivational aspects of gamification of learning. We concur with Kafai's (2006) view that learning is "building relationships between old and new knowledge, in interactions with others, while creating artifacts of social relevance" (p. 35). Creating games for STEM learning (e.g., Fields, 2015) integrates creative development alongside technical learning outcomes, adding value to technical learning without taking away from existing curriculum requirements.

Games can be defined as "a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome" (Salen & Zimmerman, 2004, p. 80). When games are applied in learning contexts with defined learning outcomes, this is called game-based learning (GBL) (Shaffer et al, 2005). As Wu et al. (Wu et al, 2012, p. 269) stated, "game-based learning is 'learning through the game', rather than 'learning to play the game'". Game-like activities are also used for learning through gamification. As per Kuo and Chuang (Kuo and Chuang, 2016, p. 17), "gamification uses game-thinking and playful design in non-game contexts, as a motivational tool to engage users".

RESEARCH METHODOLOGY

This study was conducted within the context of an engineering undergraduate course, ENCM 507, where students were asked to creatively explain the technical course concepts relating to algorithms by designing digital games. To achieve this goal, multiple stages were executed.

1. Students were asked to design and implement games based on technical concepts. The students engaged in multiple custom creativity exercises and documented their creative design process.
2. Two creative assessment instruments were developed based on existing validated

research tools: divergent creativity tests based on tests by Torrance (Torrance, 1974) and McKim (Ong, 2013), and a creativity self-efficacy assessment for before/after self-evaluation.

3. The games were tested by other faculty members and students from other units. Student participation was voluntary and conducted according to faculty ethics approval. Motivational context and entrepreneurship basis were also discussed in the class.

Analysis using the Taylor's hierarchy of creativity framework (Taylor, 1975) was conducted to understand how students move from diverse ideas to focused game design that embeds the technical concepts.

PRELIMINARY RESULTS

The project seeks to address a new teaching approach in engineering education by expanding students' creativity. In our research study, students had the opportunity to work creatively in two fundamental ways. First, during the process to transform the lessons learned in class into a conceptualized digital game and second, to overcome the project difficulties throughout the semester, considering time and resource constraints, while converting the concept into a real product.

In the game ideation phase, students (divided into groups) were engaged in transforming the algorithms learned in class into possible game mechanics. Students saw this ideation process an opportunity to exercise their creativity indeed:

> "This project began by generating potential ideas to implement. This was useful because each individual in the group was able to come up with unique ideas, and share their creativity with the other group members." (Robin)[1]

> "When I was first introduced to the project, the first thing that came to mind was that I would like to make a unique game." (Logan)

Additionally, these types of projects involve not only creativity, but as noticed by Tom, a game project involves a series of well-planned activities and different and integrated pieces of knowledge to build a meaningful and playable game:

> "Once this idea was established, the project was explored in more detail with the problem definition. General game design aspects were outlined here, such as scoring, difficulty, levels, hints, audience, etc. As well as the fact that this game would be based off a routing algorithm (A*) to calculate the optimal path through the maze/doors."

Despite the proper use of the algorithm and a well-planned project, the challenge remains in developing a game that is both entertaining and engaging for players, as pointed out by students Taylor, Jordan, and Logan. At this point, creativity is also needed:

[1] All student names mentioned are pseudonyms.

> "In terms of improving the project, there were still a few ideas that I personally felt we could improve upon and add into the game to make it more exciting and engaging to play."

> "Our game also provided a fun experience with engaging visuals, so that the user could enjoy the learning experience."

> "I wanted to give the game some more sustenance by trying to give it a story and theme."

Although the game ideation is a divergent creative process itself, the use of creativity is not restricted to just this activity. The creativity is also required in the solution of problems that emerge in the project design, as exemplified by Alex's statement about one of the problems that his group faced:

> "We had to derive an equation for the number of cells and number of nets in order to avoid duplication of lines which will mess up the scoring system".

Two particular learning activities will be refined for the next research iteration: the workshops and playtesting. The workshops were an opportunity to discuss related issues about the project and seemed to be valuable (especially in the project ideation stage) for students, helping them with some key concepts. Playtesting provided insightful feedback to refine students' games in the development phase of the project:

> "We overcame this eventually by utilizing some of design workshop concepts of problem definition and storyboarding" (Adrian).

> "This feedback enabled us to clear up confusion with our product, and gave us new ideas to implement into our final product. We were able to use this feedback to add tasks to our revised protocol checklist" (Robin).

> "During alpha testing, we did a good job of using the ideas and adding them into the game" (Andy).

Besides the creativity employed to solve the problems or "development challenges" as claimed by Andy, students also exercised a series of essential skills for engineers related to project management. Time management seemed to be a problem faced by all groups as clearly highlighted by this Alex's statement:

> "During the project, there were numerous challenges that our team has faced with, including managing time."

In addition to time management, the nature of the project, based on groups, forced the students to think about people management, a critical and desirable skill in project management:

> "... figuring out fair amount of works for everyone. Since our team was the only one that had the most team members, distributing equal amount of works for everyone was the most challenging job" (Alex).

> "Learning from our initial mistake of having five people work on the same area, we decided to split up the work and give everyone specific responsibilities as we should of initially" (Keith).

> "It was difficult to coordinate code between the team members due to conflicting schedules" (Matt).

The findings briefly presented here reinforce the well-known belief that changes in traditional learning and teaching approaches are needed. This research work has contributed to this discussion by promoting opportunities for students to experience real problems, developing their creative thinking skills to propose innovative solutions, while overcoming project constraints as they brought their ideas to life. The following two statements reveal the changes that this study promotes:

> "Designing the game has been both a challenging and enjoyable process, wherein we are able to show off our creative talents and create something that we are passionate about" (Keith).

> "The creative aspect of the design was a challenge, as we have not used creativity in our class work in a long time" (Adrian).

Used to the format of a traditional technical engineering class, students observed that creativity exercises felt unusual in a technical class, and that they would like to see more activities to help them overcome the reluctance or shyness felt. Additional research will be examined to advance the practice of establishing a creative culture in a technical classroom.

Students were also asked to consider whether they felt the creative elements of the course would be useful in their technical engineering careers. Some students reported that the creative project required them to learn new skills and it inspired them to learn more about the course material.

> “I think the creative process of solving problems will be extremely useful in my future career. This course helped me polish my creative problem solving skills even further.” (Taylor).

IMPACT

As discussed, students had opposing responses to this new approach. Some very much appreciated the opportunity to be creative, whereas others looked for more structure in the instruction and traditional measure of their progress, such as quizzes. The study experienced comparable results to a number of studies that have been conducted around student perception of project-based learning. Some students have perceptions of reduced learning efficiency and many experience feelings of uncertainty. The open-ended nature of design-based assignments can create a great deal of uncertainty for students who are used to passive consumption of ‘front-of-class’ delivery. Working in groups can also be difficult to manage with the high course loads in professional degree programs. Learning to working independently while engaging with other

learners through teamwork skills is often something that becomes apparent once students have graduated.

Through this study, we learned that in order to promote engineering students' creative designs, we also need to give them the bridging opportunities to experience and see the value of them. Many students in engineering are often trained to perform quizzes and exams well unless they pursue creative activities in their own times outside of their education. Game design, on the other hand, is a much more powerful learning tool, as they need to deeply understand the algorithms (technical outcomes) in order to use them as mechanics of the game and to imagine the interactions that occurs through game play. For the future practice of using game design in engineering courses, we will implement more structure and scaffolding activities to help them monitor their own progress and gradually move into the mode of creative design. The next phase of this study will be refined based on lessons learned, and will continue to contribute to the conversation around creativity in the technical classroom.

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