

Using Gamification for Engagement and Learning in Electrical and Computer Engineering Classrooms

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Abstract—Within technical engineering courses, students may struggle with difficult concepts, overwhelming workloads, loss of motivation and a lack of classroom engagement. Studies have shown that students who are engaged and creative in their education have improved learning outcomes in technical understanding and application. This work proposes the use of gamification for the development of both creative and technical understanding. Gamification is the application of game mechanics and typical elements of game playing (e.g. point scoring, competition with others, rules of play, etc.) to technical education as a method of encouraging student engagement with course material in a compelling and familiar way. This paper describes the development and implementation of a creative design project within an electronic design automation course, as well as a further teaching and learning research evaluation by general public focus groups.

Keywords—game-based learning; gamification; creativity; electronic design automation;

I. MOTIVATION

Electrical and computer engineers are facing several disciplinary grand challenges, such as the end of Moore's Law and the future improvement of integrated circuit (IC) design [1] [2]. Further development and innovate solutions to these grand challenges will require graduating engineers to exhibit creative thinking and problem-solving alongside technical domain knowledge mastery. Industry leaders, such as Intel, Google, and Microsoft, also recognize the need to develop these traits in future engineers, even investing their own efforts and resources into engineering education [3] [4] for the development of collaborative, creative, and motivated engineers [5] [6].

At the Schulich School of Engineering, ENCM 507 is a senior level course that can be taken as one of several technical elective requirements among electrical, computer and software engineering students. This course introduces IC design algorithms and electronic design automation concepts. Requiring mathematical theory for large-scale problems, algorithmic proofs and programming, this subject material can be very task-oriented with one correct answer, leading to a lack of problem-solving and opportunities for exploratory learning. This work proposes the use of gamification for developing student creativity and engagement alongside understanding of technical concepts.

II. PROJECT DESIGN METHODOLOGY

Gamification is the application of game mechanics and typical elements of gameplay to technical education, which may be used as a method for encouraging engagement, interest, and problem-solving [7] [8]. Game development is not dissimilar to traditional technical skill development, where progressive difficulty and student persistence are key elements of achieving the final goal [9]. Game mechanics may include aspects such as the achievement of a single or multiple goals, scoring, levels, element of chance, theme, exploration, and competition. However, rather than simply learning through gameplay, the method used in this work requires the students to learn by gamifying the technical content themselves. This technique of learner-generated game-based learning allows the students to combine a strong mastery of technical domain knowledge with creative, hands-on application.

A creative game design project was developed as a method to reinforce students' technical learning. Students were required to design an interactive program that demonstrates or utilizes an algorithm related to the course content. The project was designed with four primary factors in mind for encouraging creativity while minimizing vague requirements and large scope.

A. Engagement and Motivation

A Java-based graphics programming language called Processing was chosen as the coding development platform. This allowed the students to easily create graphics, animation, sound, and user interaction elements without the need for advanced programming knowledge or excessive coding. Students were free to design around whatever theme, hobby, or area of interest they desired, encouraging student engagement through their own interests. One student reported a desire to work on the project instead of other homework assignments due to her interest in the storytelling and theme, and motivation to produce an entertaining and quality product.

B. Autonomy and Flexibility

Minimal design constraints were applied to the project, allowing students to exercise creative freedom and flexibility. The only requirements were based around ensuring course applicability and project difficulty. Students were required to submit a proposal with a rationale describing their chosen

course-related algorithm and how it would be integrated into their design. Students were also required to storyboard their design, demonstrating how they planned to incorporate graphics, user interactions, and at least three different levels of difficulty or engagement.

C. Scope Management and Timeline

With varying ideas and scope, students were able to choose their teammates, working alone, in pairs, or in groups of three. Students were required to complete a project management schedule and breakdown of work, as well as an individual follow-up reflection. Requiring planning and accountability helped mitigate the concerns of any students who felt overwhelmed by the creative freedom and lack of structured tasks.

To assist with planning and creative design, students were also guided in a storyboarding exercise, shown in Figure 1. Used in many arts and game development industry scenarios, storyboarding allowed them to plan each stage and action of their game, which helped to identify possible issues with expanding scope or unrealistic expectations of their own programming ability.

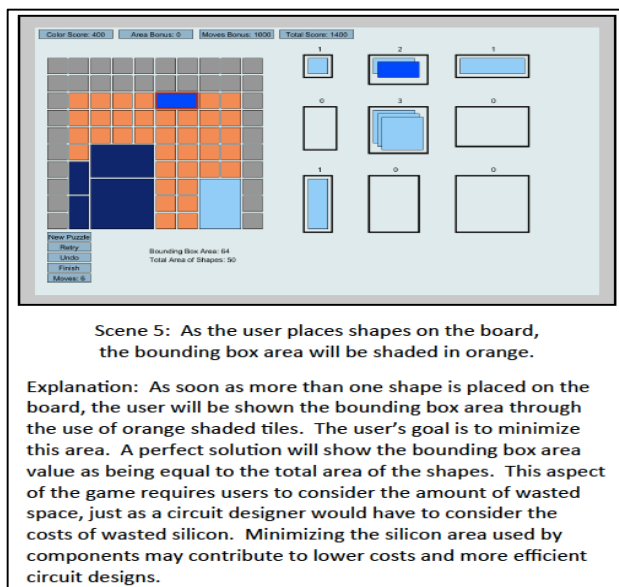


Fig. 1. A storyboarding exercise was used to assist students with their creative thinking and design planning.

D. Assessment

Students were provided with a detailed rubric that translated qualitative aspects such as engagement and creativity into quantitative criteria. Examples of “weak”, “good”, and “excellent” submissions were also given to demonstrate grading expectations. An alpha-testing session also provided informal assessment and feedback on project progress, and is described in the next section.

III. IMPLEMENTATION RESULTS

A. Alpha-Testing and Peer Feedback

An alpha-testing session was arranged for students to test their near-final products among their peers, instructor, teaching assistant, and other invited faculty members. Without the pressure of grades, students were able to solicit valuable feedback and suggestions for improving their design before submitting the final project. Students found this session to be very helpful, and the majority of the suggestions were implemented in their final code.

All students were required to rotate through demonstrating their project and trying others' projects. Each student was given a short form to complete once they had tested another program. Teams often engaged in discussions with one another over the implementation of specific features, creating an atmosphere of collaboration rather than competition.

The peer assessment form asked student to identify a) two aspects they liked or enjoyed the most, and b) one area that they felt could use improvement, with possible suggestions. For example, one team received strong feedback regarding their storyline and thematic material, but the game solution was too difficult to be achieved in the allotted time. Following feedback, this game was adjusted to eliminate difficult boundary cases from occurring, and more time was given to the user.

Following alpha-testing, students were given a couple of weeks to finish their final product and code before submission.

B. Public Perception and Learning

Because the goal of this initiative was to increase technical understanding alongside engagement and design, the projects were tested outside of the class for additional teaching and learning reflection. With ethics approval and creator permission, six final projects were demonstrated at the 2016 Calgary Comic and Entertainment Expo.

Expo attendees were invited to volunteer in focus groups to play the student-created games and provide feedback on the design, engagement, and the final solution. Focus group participants had no prior knowledge of the course or of the electronic design automation algorithms that were implemented in the game solutions. Participants were rotated through several games and, similar to the student alpha-testing session, were asked to complete a short questionnaire about each experience. Game examples are shown in Figure 2. The questions were kept short due to time restrictions, and were evaluated on a five-point Likert scale. Participants indicated how much they agreed with various statements about each game, including its creativity, its level of challenge, and its creativity. Finally, each participant was asked to write down the best way to solve each game, ideally demonstrating some understanding of the intended algorithm.

Even with the small size of the focus groups, a few trends emerged in the resulting data. The game with the highest engagement score was also perceived as the most creative. The games that were seen as the most challenging and as containing the most problem-solving were also the games that inspired the users to learn more about coding themselves. Problem-solving and a high level of challenge were also perceived as requiring

creativity from the game user. Entertainment level, however, varied across all of the games, depending on the user's interest in the theme, type of gameplay, etc.

In 33 out of 46 trials, participants were able to identify either the complete algorithm solution or demonstrate a general understanding. Participants described their solutions with domain-appropriate terms such as “minimum cost path”, “shortest path”, and “nodes”. Games that were perceived as the most creative, engaging and challenging were also the games that resulted in the most accuracy and understanding of the solution. Participants were more likely to admit to using trial-and-error or simply state “I don’t know” when it came to solving the games that were perceived as the least engaging or challenging.

These results reflect two possible outcomes that can be considered for future teaching and learning. First, that the students who put forth more effort, detail and creativity were able to demonstrate a better understanding of technical concepts in the formulation of their game, and/or second, that challenge and creativity can be used to teach electrical engineering concepts even to a non-domain specific audience. Both scenarios could be explored further for higher impact in engineering teaching and learning practices.

IV. CONCLUSIONS

The work in this paper outlines a learner-generated gamification design project for teaching advanced electrical engineering concepts. The method used incorporates engagement and motivation, autonomy and flexibility, scope management, and various assessment methods for encouraging creativity while minimizing possible stress or negative impact resulting from an unstructured design task. The final products were also tested by general public focus groups to better understand the possible impact on teaching and learning.

In general, the results from this teaching initiative show that game-based projects may be used to develop understanding of both technical domain knowledge and creative problem-solving, which are both important areas for graduating engineers facing demands for future innovation.

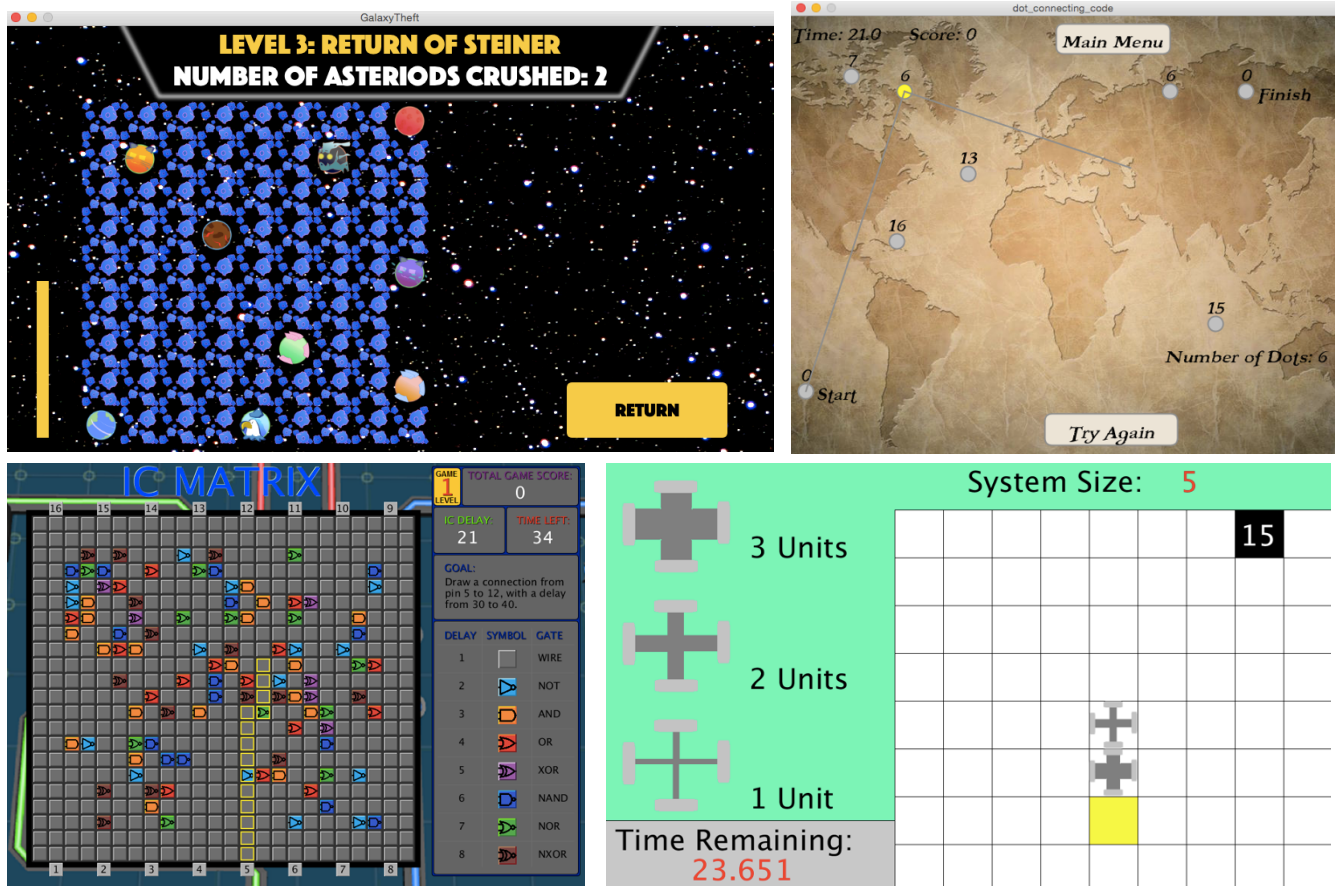


Fig. 2. Examples of learner-generated games used in the general public focus groups. Top left *Galaxy Theft* was generally considered the favourite.

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