Gamification Powered by Large Language Models in Undergraduate Computer Science

Kathleen Kelly

kathleenmariekelly@mines.edu

Colorado School of Mines

Goldon, Colorado, USA

Abstract

Gamification is a popular pedagogical approach in computer science education, and advances in large language models (LLMs) enable dynamic and engaging learning experiences. In this PhD dissertation work, gamification is being studied alongside artificial intelligence (AI) in an effort to create educational games that include personalization for each student and competition driven by AI.

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1 Context and Motivation

Instructors continuously seek pedagogical techniques to improve student engagement and motivation in educational settings. Computer science students often struggle with the course content, leading to frustration and decreased motivation [2]. Although gamification has been shown to be effective in addressing this challenge [3], developing games that balance course content with individual student needs remains difficult [9]. Meanwhile, LLMs have been shown to be a promising source of course content generation [6].

2 Background / Literature Review

Gamification is the idea of adding game elements to areas that would otherwise not be considered a game [1]. As LLMs become more popular, games have the ability to be more personalized and customized for every student's needs. Combining gamification and LLMs into the computer science classroom is an area that is still underexplored.

In related work, Mellado and Cubillos [4] found that gamification techniques were more effective than non-gamified exercises. Babu and Moorthy [8] explained that gamification helps improve student motivation, and by adding AI, the elements of the game can be dynamically adapted for each student. Montella et al. [5] used an LLM for the automatic generation of gamified exercises in a programming course. Rekha et al. [7] discussed an AI-powered system that would personalize learning according to the needs of each student.

In each of these related works, the authors were looking at ways to use gamification, LLMs, or both to improve and personalize student learning outcomes and motivation.

3 Hypothesis / Problem Statement

This dissertation research has included the creation of three different gamified learning tools. Once created, the tools are offered to students for particular durations of a semester, after which student usage is examined. The hypothesis in each study has been related to student success and motivation.

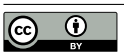
The first game created, "Engin-AIR-ing", looked at the effect of a gamified tool in a flipped classroom setting. Specifically, the following research questions were investigated: 1) Would students perform better on class quizzes if the preparatory flipped content was reinforced with an LLM-powered gamified quiz, 2) Would students be motivated by classroom material that was enhanced with gamification, and 3) Would students be more comfortable asking questions anonymously through the gamified quiz instead of in-person questions during class?

The second game created, "Quack the Code", looked at the effect of a game show where students learned while teaching their debug duck. Specifically, the following research questions were investigated: 1) If students had access to a learning tool outside of class, would they use it, 2) When using this learning tool, did the students use it as a standalone tool or in a competitive gamified manner, and 3) Did the learning tool improve students' capabilities in the course.

The third learning tool, "Bytesize Stories", is being used by students this semester. This tool specifically uses story-based learning as a way to help students master learning outcomes and increase their motivation to learn and collaborate.

4 Research Goals

In this dissertation research, the goal is to increase student motivation by offering gamified learning tools that combine software engineering content and LLM interaction. Combining gamification and generative AI allows for a more personalized experience for the students, as students have the opportunity to choose much of the game's content, generate personalized avatars, compete against AI, and learn while teaching AI. Adding LLMs as competitors in



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the game enhances the fun factor and creates an element of unpredictability. Using AI to create custom stories is an attempt to humanize and better explain a difficult topic. The generated stories are shared with all users of the tool in a community library, increasing overall student collaboration. This method of combining gamification and AI in many different approaches is a novel research study and a research gap.

5 Research Methods

For all the gamified tools created so far, research begins with the ideation and creation of the tool. Once completed, the tools are piloted to a small audience of instructors and teaching assistants. Approval is then requested from the Institutional Review Board (IRB) so the tools can be given to students and their assessment scores compared. Upon approval from IRB, students have access to the tools for the duration of the semester. Student assessment scores before and after the tool access are compared, as well as assessments of students that use the tool versus those that do not. Post-surveys and interviews are also used as research methods.

In all three tools, AI was used in some capacity. In the first tool, an LLM was used to generate game questions based on flipped classroom transcripts. The students scored points in this game based on the accuracy and speed of their responses and then the results were shown on an overall leaderboard. This tool was used for a short period of time and with limited use of AI.

In the second tool, AI was used in many more aspects. Students were able to generate a custom avatar, choose the game content, as well as the game mode, difficulty level, and type of question. This tool also included a competitive mode in which a student and a debug duck would compete against an AI opponent and a debug duck. As students answered questions, those answers would also become part of their duck's knowledge base. A "duck showdown" level would allow a student to challenge another student, using only their ducks as the contestants. After a competition, the winner would have the opportunity to claim an AI-generated prize.

The third tool is currently being used, offering story-based learning to students as a way to master the course outcomes. AI generates stories based on given learning topics and custom story details, including a title for the story, a conclusion to tie the story back to the learning outcome, quiz questions, and code samples. Students can rate the stories and share them in a community library for their peers to use.

6 Results and Contributions

The first study took place over three consecutive classes, where participating students were given access to "Engin-AIR-ing" before class, then all students were given an ungraded quiz during class. Although the number of participants was small (N = 23), **the results showed that the quiz scores of the participants increased, and the students showed a trend of interacting with the elements of the game and playing the game more than once.**

"Quack the Code" explored whether students would use a learning tool outside of class. Again, the sample size was small (N=25), but analysis showed that the majority of students played the game more than once, although most of the sessions were played using the default settings of the game. **The results showed that the default settings of the game had a huge impact on the students' selections.**

In both games, post-survey interviews were conducted. Student comments included enjoying the game elements and leaderboard, noticing an increase in their quiz scores, interacting with personalized elements, and remarking on the novelty of this work. Additionally, there was an increase in the use of "Quack the Code" in preparation for particular class assessments. **This was an exciting result, as it showed that students would use a learning tool to help prepare for an upcoming exam or quiz.** The use of "Bytesize Stories" is ongoing and will hopefully generate more exciting results in the area of gamification, generative AI and story-based learning.

Gamification has been researched as working, but limits instructors by the game itself. Future work will include giving students a role in the creation of the game. Creating this learning tool would be part of the curriculum, and the students would work together to build a game that they consider to be motivating and helpful. This would increase student participation, which has also been a bottleneck in research. By combining gamification, generative AI, and the students' own novel ideas, a perfect blend could be created to inform the field of computer science.

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