Engaging Engineering Education: A Gamification-Based Learning Approach

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***Abstract*—This work-in-progress research-to-practice paper introduces the Gamified Learning Puzzle (GLP) platform to enhance student engagement and learning effectiveness in engineering education through gamification. The GLP platform design is tailored towards the sequential and prerequisite-based nature of engineering courses whilst being extendable to other disciplines as well. The platform is developed as a web-based application, removing the need for learners to be in a specific location or use a particular device. The back-end development utilizes the Django framework, chosen for its feature-rich environment, and MySQL for robust database management.**

Key gamification elements such as "Points", "Levels/Iteration", and "Feedback" are integrated into the design to enhance the learning experience. The platform consists of two main components, the Instructor Interface and the Learner Interface. The Instructor Interface allows the course instructor to populate a question bank, organize these questions by topic, and create levels within each topic that increase in difficulty. It also enables the specification of prerequisite relationships between levels. The Learner Interface includes an uncompleted jigsaw puzzle that reveals its pieces as learners progress through the game.

Preliminary trials will involve the integration of the platform into select engineering courses at a pilot level, refining the platform based on feedback obtained from focus groups. To measure impact on students' learning experience and learning outcome, comprehensive surveys and study of pre- and post-exposure grades will be conducted. Further plans include integrating AI algorithms to provide learners with personalized feedback and assist instructors in generating content.

***Index Terms*—Educational Software, Engineering Education, Gamification, Higher Education, Learning Technology**

I. Introduction

Gamification, broadly defined as the use of game-like motivational elements in non-game contexts [1], has seen significant growth in the past decade. In recent years, use of gamification in education is suggested to be a way to inspire students to actively participate in classroom activities, equip educators with enhanced resources to effectively guide, incentivize, and encourage students to invest themselves in the learning process [2]. A quick search of publications in Engineering Education (EE) indicates that Gamification in the context of engineering education has also been on a rise in recent years. In 2020, in [3] the authors conducted a preliminary but comprehensive literature review on this topic. They indicate that the first publication regarding gamification appeared in 2011 in IEEE Xplore [3]. The authors continue to suggest that research in gamification in EE is gaining more traction. They used a "detailed selection" search criteria and showed that from 2013 to 2019 such publication numbers were increased by more than 200%. In terms of Engineering disciplines where education gamification has been applied, they show that almost 60% is in Computer Engineering, about 25% in Electrical Engineering and its sub-disciplines (including Telecommunications, Robotics, and Electronics) and 15% in other disciplines. Authors suggest that the inherent proficiency of Computer Engineering educators in the use of computer tools in gamification might be the reason for dominance of gamification in this field.

In terms of effectiveness of gamification, authors in [4] state that "gamification strategies in education are highly relevant and effective." In [5] authors implement a collaborative and

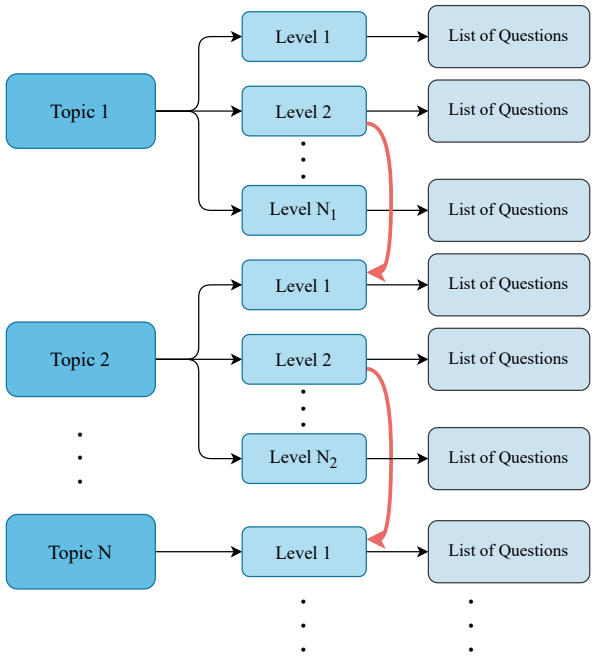

Fig. 1. Question bank structure.

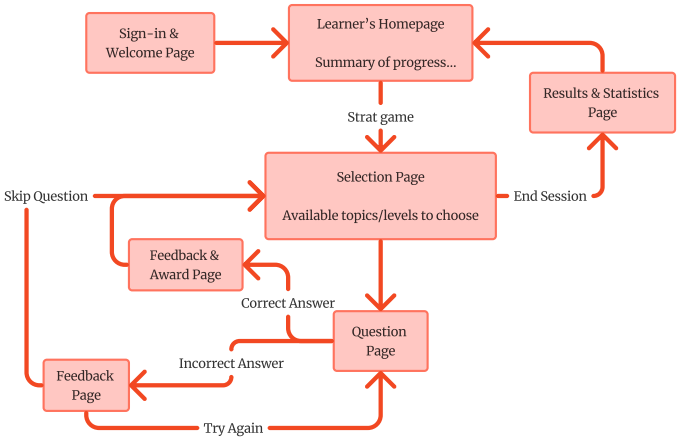

Fig. 2. Learner Interface flow of user interaction

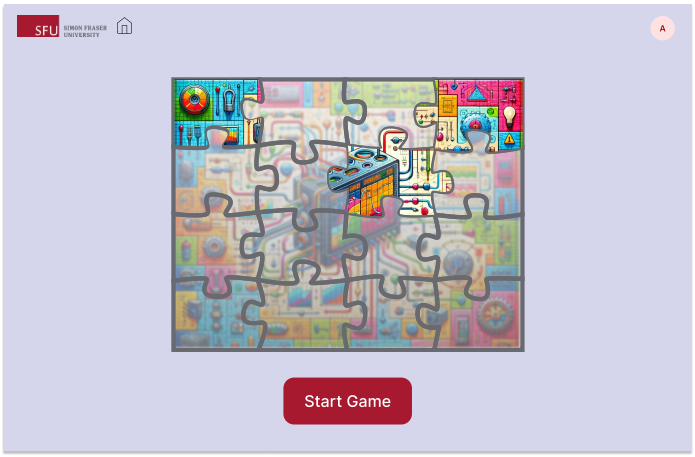

Fig. 3. GLP Home Page

playful programming learning platform. Surveys showed the aspects of the game dealing with user experience, the diversity of programming languages, and the gamification were particularly well-received by students. In [6], authors gamified a computer engineering course using a meme contest. Their surveys showed that the vast majority of students found the activity helpful, fun, and engaging. In [7], authors experimented with a personalized learning system integrated in a serious game. Educational impact of this work was measured using a set of pre- and post-tests. Although the sample size was not large enough to result in statistical significance, they showed a promising positive trend.

In [3], authors list a set of 12 "gamification elements and techniques". Their research shows that of these, the "Points" technique is most commonly used in educational gamification, whereas elements such as "Levels/Iteration" and "Feedback" are not as commonly employed in gamified education. On the other hand, when it comes to principals of learning and teaching in general, researchers have established that learning practice should be goal-directed and feedback should be targeted [8]. Furthermore, the importance of well-defined learning objectives is emphasized [8].

It can therefore be concluded that in educational gamification "Points", "Feedback", and "Levels/Iteration" are all effective techniques and elements. The reason the latter two elements are not commonly included in educational gamification might be due to the resulting increased complexity they bring to the design and implementation of the game. This WIP paper introduces a learning gamified platform tailored towards courses in engineering, referred to as the "Gamified Learning Puzzle (GLP)". The three elements listed above are the key building blocks of this platform.

The rest of this paper is organized as follows: Section II describes the general structure of the GLP Platform in II-A, followed by its user interfaces in II-B and II-C. Section III discusses future outlook for this project.

II. Overview of The Gamified Learning Puzzle

A. General Structure

The GLP platform is designed to be applicable across various learning subjects in engineering discipline although it is extendable to other disciplines as well. It consists of two user interfaces, Instructor Interface (II) and Learner (student) Interface (LI).

Course instructor uses the II to populate the question bank. Engineering courses are often of a sequential and prerequisite-based nature. They often have a structured learning path with progressive difficulty within each topic. Furthermore, they are often designed chronologically where understanding of later topics depends on the knowledge and skills acquired in earlier topics. These features are considered in the structural design of the question bank as described in more detail in Subsection II-B.

The LI includes an incomplete jigsaw puzzle with pieces being revealed as the learner progresses through the game. Unlike traditional quizzes, there is no time limit and the learner

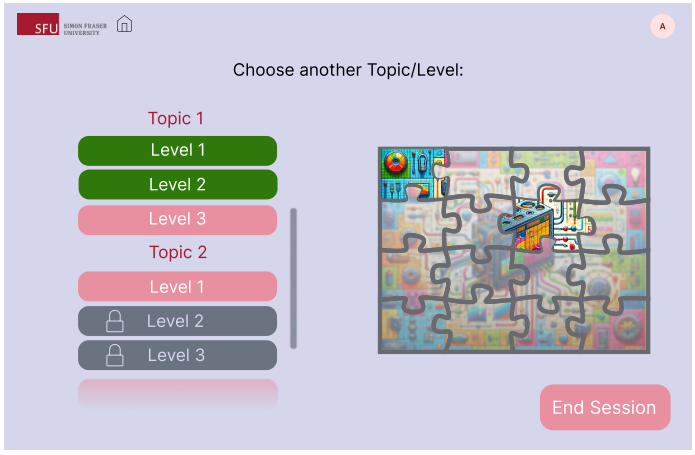

Fig. 4. Level Selection Page

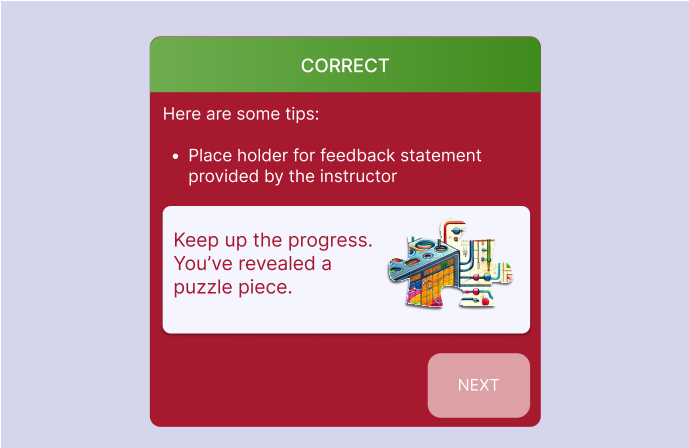

Fig. 5. Feedback and Award Page in response to correct answer

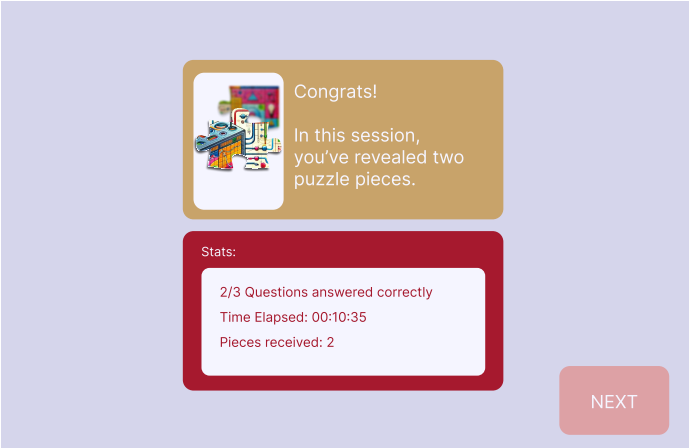

Fig. 6. Results Page demonstrating awards and statistics

can decide to progress at their own pace. The LI is described in detail in Subsection II-C.

For ease of accessibility, the GLP platform is developed as a web-based application. This approach eliminates the need for learners to be in a specific location or use a particular device. Django framework is chosen for the back-end development due to its feature-rich and well-supported nature. MySQL is used to create and manage the database for similar reasons.

B. Instructor Interface

The II is built upon the ability to populate and manipulate the question bank. Question bank structure is shown in Fig. 1. The instructor can categorize questions into various topics and levels within each topic. The implicit pre-requisite structure is from one level to the next within each topic, and from the last level of each topic to the first level of the next topic. However, the instructor has the ability to override the implicit prerequisites by adding additional pre-requisite relationships between topics and levels as they see appropriate. For example, Fig. 1, demonstrates two non-implicit prerequisite connections shown with red arrows. This provides the learner with a more personalized learning experience, where they can choose their own progress pathway. To leverage the benefit of targeted feedback, the instructor also has the ability to include feedback for each question, which can comprising of different comments in response to correct and incorrect submitted answers.

C. Learner Interface

Since the goal of this research is to motivate and engage students, the LI has been prioritized in terms of design and user interaction. The flow of interaction with the game is shown in Fig. 2. After the learner logs in the game website, they are presented with the Learner's Homepage which displays the progress they've made in completing the jigsaw puzzle during previous game sessions. Fig. 3, shows an example of the Learner's Homepage indicating that three pieces of the puzzle have so far been awarded. From there, the learner starts the game which takes them to the Selection Page. Here, the learner is presented with a list of available Topics and Levels to choose from. An example of this page is shown in Fig. 4. Levels shown in green are those already completed, those shown in pink are available to choose from, and the rest, displayed in grey, are locked due to prerequisite restrictions. After answering each question, targeted feedback is presented. If the answer is incorrect, learner can attempt the same question again or skip the question for the time being and go back to the Selection Page. If the answer is correct, learner will be awarded with a new piece of the puzzle. An example of the Feedback and Award Page can be seen in Fig. 5. From there, by clicking on the Next button the learner proceeds to the Selection Page. This page provides the learner with two options: the option to choose the next Topic/Level and thus proceed to the next question; and the option to end the current session of the game. If End Session is chosen, the game first provides a summary of the results and progress made during the current session (Fig. 6) and then goes back to the Learner's Homepage, where the overall puzzle is updated by adding the puzzle pieces revealed in the current session.

III. Future Work

In this WIP paper, an online educational gamified platform tailored towards courses taught in the engineering discipline, referred to as Gamified Learning Puzzle, is introduced.

In the immediate future, the goal is to conduct real-world trials by integrating the GLP into one or more courses offered at the School of Engineering Science at Simon Fraser University. Initially, a pilot version will be implemented and focus groups will be organized to gather feedback on the general structure of the game and its II and LI user interfaces. This stage will be conducted iteratively. After applying the necessary adjustments to the GLP, the platform will be rolled out on a larger scale. At that point, the research inquiries will be focused on students' learning outcome and learning experience. Data collection will be performed by conducting comprehensive anonymous surveys leveraging Likert Scale and open-ended questions, alongside an analysis of students' grades both before and after exposure to the game. The grades will be studied to

measure any improvement in academic performance directly attributable to the GLP. Statistical analysis of numerical results and thematic analysis of open-ended responses will be performed to assess the efficacy of our approach. It is anticipated that these stages of the research will yield preliminary results by the time the FIE'24 conference takes place.

Reinforcement Learning agents and intelligent tutoring systems have been used in gamification to achieve levels of personalized learning ([7], [9]). For the GLP platform, further plan is to employ similar AI algorithms to provide personalized feedback based on individual learner performance. This feedback will be tailored to address specific areas where a learner is struggling, offering targeted guidance to help improve understanding and skills. Additionally, AI can assist instructors in generating questions or feedback content, further enhancing the learning experience.

IV. Use of Generative AI

Authors acknowledge the use of ChatGPT (https://chat.openai.com/) to generate the image for the jigsaw puzzle. The prompt used on May 18 was "Generate a picture for a jigsaw puzzle regarding Engineering Science and Linear Control Systems." The output from this prompt was used for a demonstration of the LI of GLP.

Authors also used the same generative AI platform for minor paraphrasing of their own work. Prompts used on May 17-19 were: "Paraphrase" or "Rewrite" followed by one or two sentences of their own written sentenced.

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