ENHANCING LEARNING OF STUDENTS IN THE COMPUTING FIELD THROUGH GAMING

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CERTIFICATION

I hereby certify that this project was carried out by Adeyinka Olaseni AKINSANYA in the Department of Computer and Information Sciences, College of Science and Technology, Covenant University, Ogun State, Nigeria, under my supervision.

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DEDICATION

I dedicate this work to God, my constant source of strength and support throughout my four-year journey in this institution. I also dedicate it to my amazing friends and family, whose unwavering support and encouragement have meant so much to me.

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INTRODUCTION

1.1. Background Information

The field of computing education has long grappled with the challenge of making abstract concepts, such as data structures, algorithms, and discrete mathematics, comprehensible and engaging for students. Traditional resources, such as textbooks and video tutorials, often fail to address diverse learning needs and lack the interactivity necessary to deepen understanding. This limitation is compounded by the increasing global standards in education, which demand innovative approaches to teaching that not only convey knowledge but also foster skills such as problem-solving and critical thinking.

Gamification, the integration of game mechanics such as points, leaderboards, and rewards into non-gaming contexts, has emerged as a promising solution to these challenges. Numerous studies highlight its effectiveness in enhancing engagement and motivation across educational domains. For example, (Lavoué et al., 2021) found that gamification fosters achievement-oriented and perfection-oriented behaviours, boosting motivation and persistence in learning tasks. Similarly, a systematic review by (Jaramillo-Mediavilla et al., 2024) demonstrates that gamified learning environments significantly improve student motivation, self-learning capabilities, and academic performance when thoughtfully designed. These findings underline the potential of gamification to transform computing education by addressing its inherent challenges.

Existing educational tools, such as CodeCombat and Kahoot, demonstrate the potential of gamification in teaching programming and computational thinking. However, these tools often focus on introductory topics and lack depth in addressing more advanced computing concepts. Additionally, many gamified platforms prioritize entertainment over educational value, leading to superficial engagement with the subject matter. There remains a gap in tools designed specifically for deep and structured learning of topics like data structures and algorithms. This project seeks to bridge these gaps by creating a platform that combines gamification with rigorous, curriculum-aligned content for computing students.

Incorporating gamification into computing education will significantly improve student engagement, understanding, and retention of fundamental concepts. This project hypothesizes that game-based learning can address the shortcomings of traditional methods and existing

tools by offering an interactive and rewarding learning environment. By aligning game mechanics with educational objectives, the proposed solution has the potential to transform computing education and help students master challenging concepts effectively.

Furthermore, studies such as those by (Hooshyar et al., 2020) and (Lin et al., 2020) demonstrate the value of adaptive educational games in enhancing computational thinking through personalized feedback and interactive problem-solving experiences. Similarly, (Videnovik et al., 2023) emphasize that game-based learning not only improves cognitive skills but also sustains student engagement through dynamic instructional approaches. Despite these successes, gaps remain. Many gamified platforms fail to align with formal curricula or provide comprehensive tools for advanced topics, leading to limited educational value (Gari et al., 2018). This project addresses these limitations by integrating curriculum-aligned content and engaging game mechanics to create a holistic learning platform for computing students.

1.2. Statement of Problem

Computing education has seen significant growth with the introduction of various tools, platforms, and methodologies aimed at improving learning outcomes. However, despite these advancements, many students continue to struggle with understanding core computing concepts such as data structures, algorithms, and discrete mathematics. Existing solutions, such as video tutorials, textbooks, and online coding platforms, often fail to provide the interactivity and engagement required to sustain interest or facilitate deep comprehension. These resources typically present information in a static manner, which does not cater to diverse learning styles or offer immediate feedback. As a result, students frequently face challenges in bridging the gap between theoretical knowledge and practical application, leading to frustration and disengagement.

While gamification has shown promise in enhancing engagement and motivation in educational contexts, its application to computing education remains limited and often lacks depth. Many gamified platforms focus on introductory programming or computational thinking but fail to address the more advanced and abstract topics central to computing curricula. Additionally, these tools often prioritize entertainment over rigorous, curriculum-aligned learning. This gap presents an opportunity to leverage gamification principles to create an innovative, engaging, and effective learning platform tailored specifically to the needs of computing students.

1.3. Aim and Objectives of the Study

This research aims to design and evaluate a gamified web application to enhance the understanding of fundamental computing. The application will integrate gamification principles to foster engagement, motivation, and improved learning outcomes among computing students.

The research is guided by the following key objectives:

(i) To design and implement a gamified question-generation engine.
(ii) To develop and integrate gamification elements.
(iii) To execute gameplay scenarios and collect user performance data.
(iv) To analyse user data to identify engagement patterns.
(v) To evaluate the application's effectiveness in improving comprehension and retention of computing concepts using standard educational assessment metrics.

1.4. Methodology

(i) Review existing educational gamification techniques to develop an adaptive question-generation engine. The engine will dynamically generate questions from a database encompassing computing topics such as programming, algorithms, and data structures. The database will include hints, explanations, and varying difficulty levels to ensure personalized learning experiences. This will be implemented using Next.js for the backend and Prisma as the ORM to manage a PostgreSQL database.

(ii) Incorporate game mechanics, including badges, leaderboards, and achievements, to enhance user engagement. The platform will calculate scores based on metrics such as accuracy, response time, and question complexity. These features will be integrated using **Next.js** for server-side functionality and Framer Motion for animations to provide an engaging user experience.

(iii) Deploy the platform for testing with a sample group of computing students. The system will log user actions, question response accuracy, and time taken to answer questions. **Next.js** will handle API routes to collect gameplay data, while analytics tools such as Firebase Analytics will track performance trends. The collected data will be stored in the PostgreSQL database via Prisma for further analysis.

(iv) Convert the gameplay data into a structured dataset and perform statistical analysis to identify patterns in user engagement and learning outcomes. Python libraries such as pandas and scikit-learn will be used for data analysis. Clustering and other data visualization techniques will be applied to group users based on engagement levels and performance metrics.

(v) Conduct pre- and post-tests with participants to assess knowledge improvement. Collect qualitative feedback through surveys and focus group discussions. Use SPSS to perform inferential statistical analysis on the test results and compare the gamified platform's effectiveness against traditional learning methods. Feedback will be incorporated into iterative improvements to the platform.

Table 0.1 **Objectives-Methodology Mapping Table**

S/N	OBJECTIVES	METHODOLOGY
1.	To design and implement a gamified question-generation engine.	i. Conduct a review of existing gamification techniques and educational tools to identify features that enhance engagement and learning outcomes. ii. Develop a database schema using Prisma and PostgreSQL to store lecture materials, questions, hints, and explanations. iii. Implement the question-generation logic in **Next.js**, ensuring dynamic selection based on user performance metrics and difficulty levels. iv. Test the engine with simulated data to validate question generation, adaptability, and scalability.
2.	To develop and integrate gamification elements.	i. Design game mechanics, including scoring algorithms, leaderboards, and achievement systems, aligned with educational objectives. ii. Use **Next.js** to implement server-side logic for tracking and updating user progress. iii. Integrate animations and visual feedback using Framer Motion to enhance user engagement. iv. Conduct usability testing to ensure gamified elements are intuitive and motivating for users.
3.	To execute gameplay scenarios and collect user performance data.	i. Deploy the platform to a controlled sample of computing students, simulating various gameplay scenarios.

		ii. Use **Next.js API routes** to log gameplay data, including question response accuracy, response time, and progression metrics. iii. Implement Firebase Analytics to monitor real-time user interactions and engagement patterns. iv. Collect additional qualitative feedback through surveys to supplement quantitative performance data.
4.	To analyse user data to identify engagement patterns.	i. Convert collected gameplay data into a structured dataset using Python libraries like pandas. ii. Perform clustering analysis using scikit-learn to group users based on engagement levels, learning behaviours, and performance. iii. Visualize key trends and patterns using data visualization tools like Matplotlib or Tableau. iv. Derive actionable insights to refine gamification techniques and question-generation logic.
5.	To evaluate the application's effectiveness in improving comprehension and retention of computing concepts using standard educational assessment metrics.	i. Conduct pre- and post-tests with participants to measure knowledge retention and conceptual understanding. ii. Use SPSS for inferential statistical analysis to evaluate improvements in learning outcomes compared to traditional methods. iii. Analyse user feedback to assess satisfaction, engagement, and usability of the platform. iv. Iteratively improve the platform

		based on evaluation results, ensuring alignment with educational objectives.

1.5. Significance of the Study

This project offers significant benefits to computing students, educators, and educational institutions by providing an innovative gamified learning platform that enhances engagement, understanding, and knowledge retention. Students will gain a tailored, interactive approach to mastering complex computing concepts, while educators can use the platform as a supplementary tool with insights into student performance for targeted support. Educational institutions can adopt this technology to improve academic outcomes and foster a culture of active learning. Additionally, researchers in educational technology and gamification will find this study valuable as a reference for integrating game mechanics into education, contributing to the advancement of teaching methodologies.

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