ENHANCING LEARNING OF STUDENTS IN THE COMPUTING FIELD THROUGH GAMING

BY

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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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CHAPTER ONE

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

1.4. Methodology

(i) Collect and classify lecture materials in computing courses by reviewing computing curricula to identify core topics such as programming, algorithms, data structures, and software engineering. Gather materials from textbooks, online resources, and lecture notes, organizing them into a structured database with categories such as topic, difficulty level, and material type. Use Next.js with Prisma to implement the database schema and PostgreSQL for efficient storage and retrieval, ensuring alignment with academic objectives through expert validation.

(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.

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.

CHAPTER TWO

LITERATURE REVIEW

2.1. Preamble

This chapter provides a comprehensive and detailed review of existing literature relevant to the application of gamification in education, with a particular emphasis on its role in computing education. The chapter delves into key theories, methodologies, and tools employed in this domain, presenting evidence for both the research gap and the design choices central to the proposed solution. By highlighting the successes and limitations of current approaches, the review establishes the necessity for an innovative gamified learning platform specifically designed to address the challenges inherent in computing education. This chapter not only explores the transformative potential of gamification but also provides a contextualized analysis of how these principles can be tailored to meet the needs of learners and educators in the computing field.

2.2. Gamification in Education

Gamification is defined as the integration of game mechanics, such as points, badges, leaderboards, and rewards, into non-gaming environments to enhance user engagement and achieve desired outcomes. In the educational context, gamification has garnered significant attention for its ability to foster motivation, engagement, and improved learning outcomes across diverse disciplines. Its impact has been widely documented in numerous studies, underscoring its versatility and efficacy.

Lavoué et al. (2021) demonstrated that gamification promotes achievement-oriented and perfection-oriented behaviours among learners, significantly enhancing their motivation and persistence. This aligns with Jaramillo-Mediavilla et al. (2024), whose systematic review showed that thoughtfully designed gamified learning environments lead to substantial improvements in student motivation, self-directed learning capabilities, and academic performance. Together, these findings highlight the transformative potential of gamification when applied effectively.

Keskin et al. (2020) emphasized the role of gamification in reducing attrition rates in Massive Open Online Courses (MOOCs) by leveraging mechanisms such as badges and reward systems to increase student participation and motivation. Their work underscores the importance of tailoring gamification strategies to align with the diverse needs of learners.

Similarly, Rizzardini et al. (2016) found that gamification elements such as progress tracking and rewards significantly enhance student engagement, provided they are aligned with learning objectives. These findings form the basis for the inclusion of adaptive mechanics in this project's design to accommodate varied learner profiles.

Moreover, gamification is not only effective in fostering a sense of accomplishment but also in creating an enjoyable learning experience that encourages sustained engagement. However, to maximize its benefits, it is crucial to balance motivational elements with the cognitive demands of the learning material. Overuse of competitive features, for instance, can lead to unintended stress and disengagement, necessitating careful and thoughtful design choices.

2.3. Applications of Gamification in Computing Education

Computing education has increasingly adopted gamification to address the challenges of teaching complex subjects such as programming, algorithms, and computational thinking. Tools like CodeCombat and Kahoot exemplify the potential of gamification to transform abstract computing concepts into interactive and engaging learning experiences. However, despite these successes, significant gaps remain in the application of gamified approaches to advanced computing topics.

Hooshyar et al. (2020) explored the use of adaptive educational games to enhance computational thinking, demonstrating that personalized feedback and interactive problem-solving significantly improve student engagement and understanding. Similarly, Lin et al. (2020) highlighted the potential of game-based smart toys to enhance computational thinking skills among younger learners, emphasizing the adaptability of gamified approaches across age groups and expertise levels. These studies provide strong evidence for incorporating personalized feedback and interactive elements into the proposed gamified platform.

However, Videnovik et al. (2023) cautioned that many existing tools prioritize entertainment over educational depth, leading to superficial engagement. Swacha (2021) similarly observed that poorly designed gamified tools in computer science education can inadvertently reduce intrinsic motivation, underscoring the need for gamification strategies that align with formal curricula and promote meaningful learning. These findings highlight the necessity of designing a platform that combines engaging gamification elements with rigorous educational content, specifically tailored to the challenges of advanced computing topics.

2.4. Gamification Elements and Their Impact

Gamification incorporates a variety of elements to enhance learning experiences. Key elements include:

(i) **Points and Scoring**: Track progress and provide immediate feedback to motivate learners.

(ii) **Badges and Achievements**: Recognize accomplishments and foster a sense of pride and progression.

(iii) **Leaderboards**: Promote competition and collaboration among learners, encouraging them to strive for higher performance.

Lavoué et al. (2021) argued that these elements, when combined with meaningful feedback mechanisms, significantly enhance learning by maintaining motivation and focus. Oliveira et al. (2022) emphasized the importance of tailoring gamification strategies to individual learner preferences to optimize engagement and learning outcomes. However, they also noted the potential drawbacks of overemphasizing competition, which can lead to stress or reduced participation for some learners. This highlights the importance of creating balanced and inclusive gamification designs.

Troussas et al. (2019) explored the integration of adaptive feedback into gamified environments, showing that personalized recommendations enhance student engagement and improve learning outcomes. This finding supports the decision to incorporate adaptive feedback mechanisms into the proposed platform to cater to diverse learner needs effectively.

2.5. Adaptive Learning Through Gamification

Adaptive learning tailors educational experiences to individual learners by adjusting content and difficulty levels based on user performance. This approach ensures that learners remain appropriately challenged, fostering continuous engagement and growth. Hooshyar et al. (2020) demonstrated that adaptive educational games improve engagement by dynamically adjusting challenges to match learner capabilities, a principle central to the proposed project's design.

The importance of adaptability is further emphasized by Troussas et al. (2019), who investigated the use of fuzzy-modelled personalization in mobile game-based learning. Their findings indicate that tailored feedback and personalized recommendations significantly enhance learning experiences, supporting the integration of similar adaptive mechanisms into the proposed platform. Adaptive gamification not only sustains engagement but also promotes a growth mindset by encouraging learners to tackle progressively challenging tasks without feeling overwhelmed.

2.6. Review of Existing Systems

2.7. Challenges and Limitations of Existing Tools

Despite the potential of gamification, existing tools face several limitations:

(i) **Focus on Introductory Topics**: Platforms like Kahoot primarily cater to beginners, neglecting the needs of advanced learners. For example, while these tools excel at introducing basic concepts, they often fail to provide the depth required for mastering complex topics such as advanced algorithms or system design. This gap leaves learners unprepared for real-world applications of computing knowledge.

(ii) **Limited Curriculum Alignment**: Many tools prioritize engagement over alignment with formal educational standards (Gari et al., 2018). This misalignment reduces their effectiveness in supporting structured learning paths. Tools that fail to align with curricula may also overlook critical concepts, thereby impeding the holistic development of learners.

(iii) **Superficial Engagement**: Entertainment often takes precedence over educational value, limiting the development of critical thinking skills. This issue is compounded when tools rely excessively on gamified elements without integrating meaningful educational content. As a result, learners may find the experience enjoyable but fail to acquire deeper knowledge or skills.

(iv) **Scalability Issues**: Existing platforms struggle to address the diverse needs of learners across varying expertise levels. For instance, while beginners benefit from basic gamified tasks, advanced learners often require complex and adaptive

challenges to remain engaged. A lack of scalability hinders the ability to cater to this broad spectrum of needs, leaving many learners underserved.

(v) **Feedback Deficiencies**: Many tools provide generic feedback, which limits the learner's ability to understand and improve specific weaknesses. Personalized and actionable feedback is essential for fostering skill development and ensuring that learners can effectively bridge knowledge gaps.

These challenges underscore the necessity for a gamified learning platform that integrates curriculum-aligned content with engaging, adaptive, and meaningful game mechanics. By addressing these gaps, the proposed platform aims to support deep and structured learning, particularly in advanced computing topics. Furthermore, incorporating advanced features such as dynamic question adaptation, comprehensive progress tracking, and personalized feedback can transform the learning experience into one that is not only engaging but also educationally robust. The focus on scalability and curriculum alignment ensures that the platform remains relevant across a wide range of educational contexts, making it a versatile tool for learners at all levels.

2.8. Summary and Conclusion

REFERENCES

Gari, M. R. N., Walia, G., & Radermacher, A. (2018). *Gamification in Computer Science Education: a Systematic Literature Review*. https://www.semanticscholar.org/paper/Gamification-in-Computer-Science-Education%3A-a-Gari-Walia/7fbf60f1ca15349e6acfe35935586c7473164bb6

Hooshyar, D., Malva, L., Yang, Y., Pedaste, M., Wang, M., & Lim, H. (2020). An adaptive educational computer game: Effects on students' knowledge and learning attitude in computational thinking. *Computers in Human Behavior*, *114*, 106575. https://doi.org/10.1016/j.chb.2020.106575

Jaramillo-Mediavilla, L., Basantes-Andrade, A., Cabezas-González, M., & Casillas-Martín, S. (2024). Impact of Gamification on Motivation and Academic Performance: A Systematic Review. *Education Sciences*, *14*(6), 639. https://doi.org/10.3390/educsci14060639

Lavoué, E., Ju, Q., Hallifax, S., & Serna, A. (2021). Analyzing the relationships between learners' motivation and observable engaged behaviors in a gamified learning environment. *International Journal of Human-Computer Studies*, *154*, 102670. https://doi.org/10.1016/j.ijhcs.2021.102670

Lin, S.-Y., Chien, S.-Y., Hsiao, C.-L., Hsia, C.-H., & Chao, K.-M. (2020). Enhancing Computational Thinking Capability of Preschool Children by Game-based Smart Toys. *Electronic Commerce Research and Applications*, *44*, 101011. https://doi.org/10.1016/j.elerap.2020.101011

Oliveira, W., Hamari, J., Shi, L., Toda, A. M., Rodrigues, L., Palomino, P. T., & Isotani, S. (2022). Tailored gamification in education: A literature review and future agenda. *Education and Information Technologies*, *28*(1), 373–406. https://doi.org/10.1007/s10639-022-11122-4

Rizzardini, R. H., Chan, M. M., & Guetl, C. (2016). An Attrition Model for MOOCs. In *Elsevier eBooks*. https://doi.org/10.1016/b978-0-12-803637-2.00014-2

Swacha, J. (2021). State of Research on Gamification in Education: A Bibliometric Survey. *Education Sciences*, *11*(2), 69. https://doi.org/10.3390/educsci11020069

Troussas, C., Krouska, A., & Sgouropoulou, C. (2019). Collaboration and fuzzy-modeled

personalization for mobile game-based learning in higher education. *Computers & Education*, *144*, 103698. https://doi.org/10.1016/j.compedu.2019.103698

Videnovik, M., Bogdanova, A. M., & Trajkovik, V. (2023). Game-based learning approach in computer science in primary education: A systematic review. *Entertainment Computing*, *48*, 100616. https://doi.org/10.1016/j.entcom.2023.100616

Videnovik, M., Vold, T., Kiønig, L., Bogdanova, A. M., & Trajkovik, V. (2023). Game-based learning in computer science education: a scoping literature review. *International Journal of STEM Education*, *10*(1). https://doi.org/10.1186/s40594-023-00447-2