ENHANCING LEARNING OF STUDENTS IN THE COMPUTING FIELD THROUGH GAMING

BY

AKINSANYA, ADEYINKA OLASENI

(21CG029820)

A PROJECT PROPOSAL SUBMITTED TO THE DEPARTMENT OF COMPUTER AND INFORMATION SCIENCES, COLLEGE OF SCIENCE AND TECHNOLOGY, COVENANT UNIVERSITY, OTA, OGUN STATE.

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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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ABBREVIATIONS

API	Application Programming Interface
GPT	Generative Pretrained Transformer
MOOC	Massive Open Online Course
RPG	Role Playing Games
SPSS	Statistical Package for the Social Sciences

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 (Wiredu *et al.*, 2024).

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 (Triantafyllou *et al.*, 2024).

1.3. Aim and Objectives of the Study

The aim of this research is to design and evaluate a gamified web application to enhance the understanding of fundamental computing concepts. 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)** Design and implement a gamified question-generation engine that dynamically creates questions from the structured database. Use Next.js for backend functionality and React for the user interface to facilitate seamless interaction. Integrate OpenAI’s GPT-4 to enhance adaptive question generation, enabling the platform to create questions that adjust in difficulty based on learner performance.

Implement adaptive algorithms that use GPT-4's natural language processing capabilities to analyse user responses and tailor questions accordingly. Incorporate features such as hints and explanations provided by GPT-4 to support comprehension and maintain learner engagement.

(iii) Develop and integrate gamification elements, including interactive components such as badges, leaderboards, and achievement systems, to enhance user engagement and motivation. Calculate scores based on metrics like response accuracy, time taken, and question complexity. Integrate these features using Next.js for server-side processing and Framer Motion for animations to create an engaging and visually appealing user experience.

(iv) Deploy the platform for testing with a sample group of computing students. Log user actions, question response accuracy, and time taken to complete tasks using Next.js API routes. Use Firebase Analytics to track user performance trends, with data stored in PostgreSQL via Prisma for structured analysis.

(v) Analyse user data and identify engagement patterns by processing gameplay data with Python libraries such as pandas and scikit-learn. Apply clustering and data visualization techniques to group users based on engagement levels and performance metrics, providing insights into learner behaviour and identifying effective platform features that maintain interest and support learning.

(vi) Conduct pre- and post-tests with participants to assess improvements in comprehension and retention. Collect qualitative feedback through surveys and focus group discussions to understand user experiences and perspectives. Perform inferential statistical analysis using SPSS to compare the effectiveness of the gamified platform against traditional learning methods. Use the findings to inform iterative improvements, optimizing the platform to enhance engagement, comprehension, and retention of computing concepts.

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.

Karsen *et al.* (2022) 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. The following are some of the applications:

2.3.1. Programming Education

Game-based platforms like CodeCombat and CodeMonkey utilize interactive storytelling and role-playing to teach programming concepts. These platforms simplify complex syntax and logic by embedding coding tasks into engaging narratives, making coding more accessible for beginners and intermediate learners alike. These games use a step-by-step approach, allowing learners to gradually build confidence in their programming skills through guided challenges.

In addition to basic syntax and logic, these platforms often introduce foundational concepts such as loops, conditionals, and functions. For instance, CodeCombat allows users to solve puzzles using programming languages like Python or JavaScript, helping learners bridge the gap between theoretical understanding and practical application (Kroustalli & Xinogalos, 2021). This hands-on learning approach encourages active problem-solving and fosters long-term retention of knowledge.

Furthermore, incorporating gamification into programming education has shown significant motivational benefits. Gamified tasks such as earning points, unlocking levels, and receiving real-time feedback incentivize learners to persist through challenges. This persistence is particularly valuable in programming, where learners often encounter steep learning curves.

Studies have highlighted the effectiveness of these motivational strategies in reducing learner attrition and increasing engagement in technical courses (Karsen *et al.*, 2022).

However, challenges remain in designing gamified programming platforms that cater to a diverse range of learners. Advanced learners may find repetitive or simplistic tasks unengaging, while beginners might feel overwhelmed by complex challenges. Adaptive gamification, which tailors tasks to individual proficiency levels, offers a promising solution to address these issues, ensuring that all learners remain appropriately challenged.

2.3.2. Algorithm Visualization

Gamified tools such as AlgoBot employ visualizations to explain algorithmic processes, providing learners with interactive environments where they can observe and manipulate data structures in real-time. These tools transform abstract concepts, like sorting algorithms or graph traversals, into dynamic and tangible experiences, enhancing comprehension and engagement.

Interactive visualization tools offer several advantages over traditional teaching methods. For instance, learners can experiment with algorithm parameters, observe their effects on performance, and identify errors in their logic through trial and error. By actively engaging with algorithms, students develop a deeper understanding of how they function and why they are applied in specific scenarios.

The effectiveness of algorithm visualization has been demonstrated in several studies. Research indicates that visual and interactive learning environments improve learners' ability to recall and apply algorithmic concepts (Swacha, 2021). For example, tools that gamify algorithmic learning by incorporating levels, challenges, and rewards motivate learners to explore complex topics that might otherwise seem intimidating.

Despite their benefits, algorithm visualization tools face limitations. These include a reliance on high-quality graphical interfaces and the challenge of aligning gamified tasks with standardized curricula. Addressing these limitations requires collaboration between educators, developers, and instructional designers to ensure that gamified visualization tools meet educational standards while maintaining their engaging qualities.

2.3.3. Computational Thinking

Platforms like Lightbot and Blockly encourage computational thinking by engaging learners in structured problem-solving activities that mimic real-world coding challenges.

Computational thinking, which includes skills such as pattern recognition, abstraction, and decomposition, is essential for success in computing disciplines and is effectively cultivated through gamified learning environments.

Gamified computational thinking platforms often use puzzles and challenges to develop these critical skills. Lightbot, for instance, requires learners to guide a robot through a series of tasks by programming its movements. This process encourages learners to think critically about the sequence and logic of their commands, fostering problem-solving abilities in an intuitive and enjoyable way (Hooshyar *et al.*, 2020).

Additionally, these platforms provide immediate feedback, allowing learners to identify and correct errors in their logic. This iterative process of trial and improvement mirrors real-world software development, where debugging and optimization are critical. Studies have shown that this hands-on, trial-and-error approach significantly enhances learners' ability to tackle complex problems (Troussas *et al.*, 2019).

While these tools are highly effective for introducing computational thinking to novices, they may not fully address the needs of advanced learners. To bridge this gap, future iterations of gamified platforms could incorporate adaptive difficulty settings and more complex problem-solving scenarios, ensuring that learners of all levels are adequately challenged.

2.3.4. Systems Analysis and Design

Simulation games like Simulink provide learners with practical experiences in systems modelling and analysis. These tools enable students to create, test, and refine system designs in simulated environments, bridging the gap between theoretical knowledge and real-world application. By offering a risk-free platform for experimentation, simulation games foster creativity and innovation.

Systems analysis and design involve understanding and addressing complex interactions within systems. Gamified simulation tools break down these complexities into manageable tasks, allowing learners to focus on specific components of a system before integrating them into a cohesive whole. This modular approach aligns with constructivist learning theories, which emphasize the importance of building knowledge incrementally (Schumacher *et al.*, 2022).

Furthermore, simulation games often incorporate realistic scenarios that mirror industry challenges. For example, learners might design a network infrastructure or optimize a

production process, applying theoretical concepts to solve practical problems. This contextualized learning approach not only reinforces technical skills but also develops critical thinking and decision-making abilities (Salunkhe *et al.*, 2024).

Despite their advantages, gamified simulation tools require significant resources to develop and maintain. High-quality graphics, robust algorithms, and user-friendly interfaces are essential for creating effective learning environments. Collaboration with industry stakeholders can help ensure that these tools remain relevant and up to date with technological advancements.

2.3.5. Cybersecurity Training

Role-playing games (RPGs) designed for cybersecurity education immerse learners in realistic scenarios that require identifying, analysing, and mitigating security threats. These games offer hands-on experience in critical areas such as network defence, threat detection, and incident response, providing learners with practical skills in a controlled and engaging environment.

Cybersecurity RPGs often simulate high-stakes scenarios, such as responding to a data breach or securing a vulnerable system. By placing learners in active roles, these games encourage critical thinking, teamwork, and strategic planning. Research indicates that gamified cybersecurity training significantly improves learners' ability to apply theoretical knowledge to practical situations (Swacha, 2021).

In addition to technical skills, cybersecurity RPGs foster soft skills such as communication and collaboration. For instance, multiplayer scenarios may require teams to coordinate their efforts to address complex threats, mirroring real-world cybersecurity operations. These collaborative elements enhance the overall learning experience, preparing students for professional environments.

However, developing effective cybersecurity RPGs presents unique challenges. These include creating realistic and varied scenarios, ensuring alignment with industry standards, and maintaining accessibility for learners with diverse backgrounds. Addressing these challenges requires input from educators, industry experts, and game designers to create comprehensive and effective training tools.

2.4. Gamification Elements and Their Impact

Gamification incorporates a variety of elements to enhance learning experiences. Each gamification element contributes uniquely to the overall impact, ensuring a more engaging and effective educational process. Below is an extensive discussion of the key elements:

2.4.1. Points and Scoring

Points and scoring systems are foundational elements of gamification that provide learners with immediate feedback and a tangible sense of progress. By assigning points for completing tasks, answering questions correctly, or achieving specific milestones, these systems incentivize participation and reward effort.

The psychological impact of earning points is significant. Research shows that points trigger the brain's reward system, releasing dopamine and creating positive reinforcement (Lavoué *et al.*, 2021). This immediate gratification motivates learners to continue engaging with the material, fostering a sense of accomplishment and driving consistent participation.

Moreover, points serve as a metric for tracking progress, allowing learners to visualize their improvement over time. This visibility can be particularly motivating for students in challenging subjects, as it highlights incremental achievements that might otherwise go unnoticed. Teachers and educators can also use points as a diagnostic tool to identify areas where students may need additional support.

However, the design of point systems must be carefully balanced to avoid unintended consequences. For instance, overemphasis on point accumulation can lead to extrinsic motivation, where learners focus solely on earning points rather than mastering the subject matter. To address this, educators can combine points with other gamification elements, such as meaningful feedback and rewards, to maintain intrinsic motivation.

Finally, points and scoring systems can be integrated into adaptive learning environments, where tasks are adjusted based on performance. This ensures that learners are continuously challenged at an appropriate level, maximizing engagement and knowledge retention.

2.4.2. Badges and Achievements

Badges and achievements are visual representations of accomplishments that recognize learners’ efforts and milestones. These elements foster a sense of pride and progression, motivating students to pursue further achievements and complete tasks.

Badges often serve as markers of specific competencies or skills, such as mastering a programming concept or completing a challenging algorithm exercise. This recognition not only boosts learners' confidence but also provides them with tangible evidence of their progress. Employers and institutions can also use badges as indicators of proficiency in specific areas (Rizzardini *et al.*, 2016).

The psychological benefits of badges extend beyond individual motivation. Studies show that public displays of achievements, such as digital badges visible on leaderboards or profiles, encourage friendly competition and collaboration among peers (Oliveira *et al.*, 2022). This social aspect of gamification can create a supportive learning community, where learners motivate each other to succeed.

However, the effectiveness of badges depends on their relevance and alignment with educational objectives. Badges that are too easy to earn may lose their value, while overly complex or ambiguous criteria can discourage learners. Therefore, it is essential to design badges that strike a balance between accessibility and challenge.

Incorporating hierarchical achievements, where learners unlock advanced badges by building on foundational skills, can further enhance the learning experience. This approach encourages sustained engagement and progression, guiding learners through increasingly complex material.

2.4.3. Leaderboards

Leaderboards rank learners based on their performance, fostering a sense of competition and collaboration. By displaying rankings publicly or within a group, leaderboards create an environment where students are motivated to improve their standing.

The competitive nature of leaderboards can be a powerful motivator for learners, particularly in subjects that require sustained effort and practice. For example, students might strive to solve more programming challenges or complete assignments faster to climb the leaderboard. This dynamic encourages active participation and continuous improvement (Li *et al.*, 2024).

In addition to individual motivation, leaderboards can promote collaboration. Group leaderboards, where teams compete against each other, foster teamwork and communication skills. This collaborative aspect is particularly valuable in computing education, where problem-solving often involves working with others to develop solutions.

Despite their benefits, leaderboards must be implemented thoughtfully to avoid negative effects. Overemphasis on rankings can create stress or discourage learners who struggle to compete with high performers. To mitigate this, educators can use tiered leaderboards, which group learners into categories based on skill level. This approach ensures that all students can experience the benefits of competition without feeling overwhelmed.

Furthermore, integrating leaderboards with other gamification elements, such as points and badges, can enhance their effectiveness. For instance, displaying badges alongside rankings can highlight individual strengths and achievements, fostering a more inclusive and supportive learning environment.

2.4.4. Rewards and Incentives

Rewards and incentives are integral to gamification, providing learners with tangible or intangible benefits for their achievements. These elements create a sense of anticipation and satisfaction, motivating students to engage with the material and complete tasks.

Rewards can take various forms, such as virtual items, certificates, or even privileges within the learning platform. For example, learners might earn tokens that can be exchanged for hints or additional resources. These incentives add an element of fun and excitement to the learning process, making it more enjoyable and memorable (Troussas *et al.*, 2019).

The timing and delivery of rewards are crucial to their effectiveness. Immediate rewards, such as feedback or small tokens, reinforce positive behaviour and encourage learners to continue their efforts. On the other hand, delayed rewards, such as completing a course or achieving a major milestone, provide a sense of accomplishment and closure.

While rewards are effective in driving engagement, they should be used judiciously to avoid over-reliance on extrinsic motivation. Balancing rewards with intrinsic motivators, such as personal growth and mastery of skills, ensures that learners remain committed to their educational goals beyond the gamified elements.

Lastly, incorporating personalized rewards, tailored to individual preferences and achievements, can enhance their impact. For instance, allowing learners to choose their rewards or setting personalized goals adds a layer of autonomy and relevance to the gamified experience.

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

This section evaluates and discusses established systems designed to enhance student learning in the computing field through gaming. This review aims to identify how gamification and game-based learning have been implemented to improve engagement, foster problem-solving skills, and facilitate deeper understanding of computing concepts. Here is a brief overview of some of systems that make use of gamification in computing education:

2.6.1. CodeCombat

CodeCombat is an engaging, game-based platform designed to teach coding through interactive gameplay. Players write real code to solve challenges, guiding characters through various levels of a fantasy-themed world. This platform bridges the gap between theoretical learning and practical application by embedding programming tasks into a dynamic and enjoyable environment. It supports languages like Python and JavaScript, offering a hands-on learning approach that makes coding intuitive and fun.

One of CodeCombat's standout features is its interactive gameplay, where learners solve puzzles and complete in-game objectives by writing actual code. This method helps students grasp complex programming concepts like loops, conditionals, and functions in an intuitive

and experiential manner. The fantasy-themed world and engaging narrative further immerse players, creating a motivating and stress-free learning environment.

The platform's multi-language support enables users to learn programming languages such as Python, JavaScript, and others, accommodating diverse learner preferences and career aspirations. By introducing real-world languages early, CodeCombat prepares students for advanced programming tasks and professional environments. Additionally, the platform offers challenges tailored to different skill levels, ensuring accessibility for beginners and a robust challenge for more advanced learners (Choi, 2024).

CodeCombat also provides educator tools, including dashboards that allow teachers to track student progress, customize lesson plans, and identify areas requiring additional focus. This feature makes it an excellent resource for classroom integration, enabling structured and guided learning. Educators can leverage these tools to create personalized learning experiences, fostering a deeper understanding of programming concepts.

Despite its numerous advantages, CodeCombat faces some challenges, such as limited coverage of advanced programming topics. While it excels at introducing foundational concepts, learners aiming for expertise in topics like data structures or algorithms may need supplementary resources. Nevertheless, CodeCombat remains a powerful tool for fostering early interest and competence in programming.

Figure 2.1: CodeCombat Interface

2.6.2. Roblox Education

Roblox Education leverages the popular Roblox game development platform to teach computing and creative skills. This program allows students to create and publish their own games, providing hands-on experience in programming and game design. By combining education with an already familiar and engaging platform, Roblox Education enhances learning in a fun and collaborative environment.

The game creation tools within Roblox Education empower learners to design, build, and share their projects, offering them full creative control. This process introduces programming concepts through Lua scripting, a language widely used in game development. Students gain a practical understanding of coding and its applications, bridging the gap between theory and practice.

Roblox Education emphasizes collaboration, encouraging students to work on shared projects and engage with a larger community of creators. This collaborative approach fosters teamwork, communication, and problem-solving skills—essential competencies in the computing field. Through peer interactions, students also learn to critique and refine their work, enhancing their creativity and technical expertise (Han *et al.*, 2023).

The platform also offers career preparation opportunities by introducing students to real-world game development workflows and entrepreneurial skills. By creating and monetizing games, learners acquire knowledge about project management, user engagement, and revenue generation, providing a comprehensive view of the game development industry. These features make Roblox Education not just an educational tool but also a gateway to potential career pathways.

However, a potential limitation is the platform's focus on game development, which might not address broader computing topics like algorithms or cybersecurity. Expanding its curriculum to include these areas could make Roblox Education a more versatile resource for computing education.

2.6.3. CodinGame

CodinGame is a unique platform that blends competitive programming with gamification, creating an engaging environment for learners to hone their coding skills. Users solve algorithmic problems by writing code that controls game elements, such as navigating a

spaceship or optimizing processes in a simulated factory. The platform supports over 25 programming languages, catering to a diverse audience with varying skill levels.

One of CodinGame's most appealing features is its multiplayer challenges, where users engage in real-time coding battles with others. This competitive aspect fosters a sense of community and motivates participants to improve their skills. These challenges also encourage strategic thinking and adaptability, as players must develop efficient solutions under time constraints.

The platform's variety of languages supported ensures accessibility for learners and professionals alike. From Python and JavaScript to niche languages like Rust, CodinGame accommodates a wide range of programming preferences. This inclusivity allows users to practice their preferred languages while exploring new ones, broadening their technical expertise.

CodinGame's focus on problem-solving is another key strength. The platform offers diverse puzzles that challenge users to think logically and develop efficient algorithms. These tasks simulate real-world programming scenarios, helping learners build practical skills applicable to professional environments. The integration of coding into game mechanics further enhances the learning experience by making abstract concepts tangible and engaging (Butt, 2016).

Despite its strengths, CodinGame may not cater well to complete beginners, as its challenges often require a basic understanding of programming. Incorporating more beginner-friendly tutorials could expand its accessibility. Nonetheless, CodinGame remains an excellent resource for intermediate to advanced learners aiming to refine their coding and problem-solving skills.

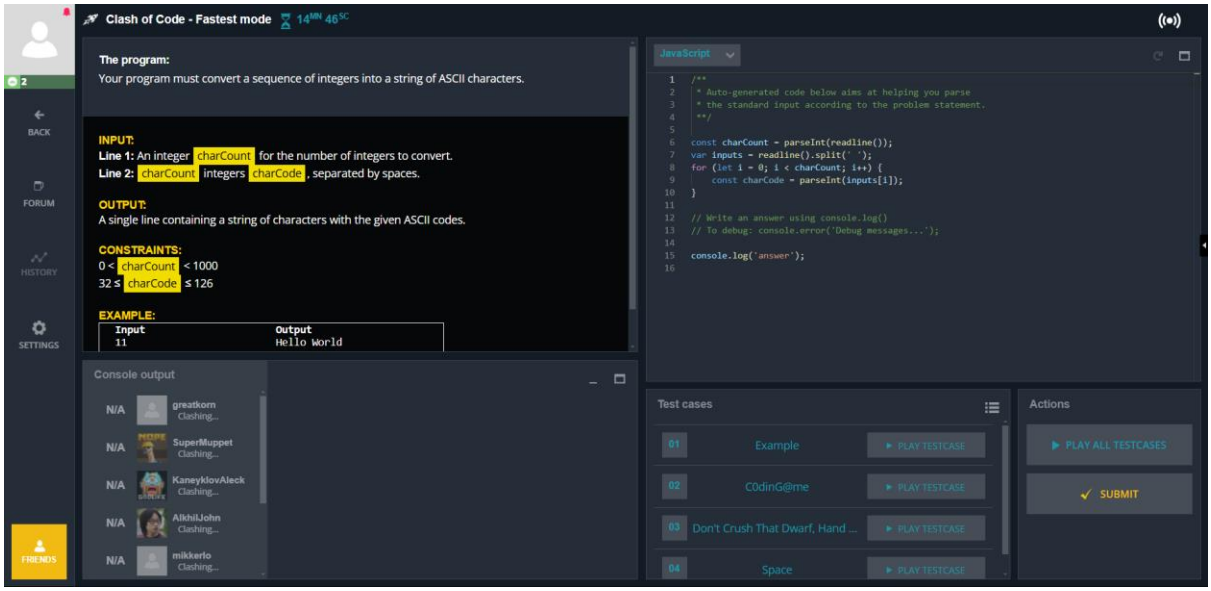

Figure 2.2: CodinGame Interface

2.6.4. Lightbot

Lightbot is an educational puzzle game that introduces students to programming logic through gameplay. Players guide a robot to light up tiles by using programming fundamentals such as loops, conditionals, and procedures. This platform simplifies coding concepts, making it accessible to younger learners while remaining effective for teaching essential skills.

The game's intuitive learning path employs a step-by-step approach, gradually introducing new programming concepts as players progress through levels. This method ensures that learners build a solid foundation before tackling more complex challenges. The simplicity of Lightbot's design makes it particularly suitable for beginners, fostering early interest and confidence in programming.

Lightbot emphasizes a focus on coding logic, teaching essential concepts like loops and conditionals in a fun, interactive way. By solving puzzles, learners develop critical thinking and problem-solving skills, which are fundamental to success in computing disciplines. The visual and hands-on nature of the gameplay makes abstract concepts more concrete and understandable (Lee, 2020).

The platform's progressive difficulty levels ensure continuous learning and skill-building. As players advance, puzzles become more complex, requiring a deeper understanding of programming logic and the ability to apply learned concepts creatively. This gradual

progression helps maintain engagement and motivation, preventing learners from becoming overwhelmed.

While Lightbot excels at introducing programming basics, its scope is limited to foundational concepts. Expanding its curriculum to include more advanced topics could enhance its utility for older or more experienced learners. Nevertheless, Lightbot remains an invaluable tool for initiating young students into the world of programming.

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 CodeCombat 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 (Chuang *et al.*, 2024). 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.

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

This chapter has provided an in-depth review of the existing literature related to gamification in education, with a focus on its application in computing education. The findings highlighted the transformative potential of gamification as a tool to increase learner engagement, motivation, and performance. Key gamification elements such as points, badges, leaderboards, and rewards were examined for their roles in fostering student participation and learning.

In the context of computing education, applications such as programming tutorials, algorithm visualizations, and computational thinking platforms were reviewed for their effectiveness in promoting understanding and skill development. Notably, while tools like CodeCombat, AlgoBot, and simulation-based learning platforms provide interactive and engaging learning experiences, challenges persist. Limitations include a focus on introductory topics, limited curriculum alignment, superficial engagement, scalability issues, and inadequate feedback mechanisms.

The literature review underscored the necessity for a gamified learning platform that integrates curriculum-aligned content with adaptive, interactive game mechanics to overcome these challenges. This proposed platform aims to address gaps identified in the literature by incorporating elements that foster deep learning, adaptive learning paths, and personalized feedback.

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