Implementation of Gamification in Programming Learning: Literature Review

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***Abstract*—Student motivation is one of many issues within programming learning. For a variety of reasons, students consider programming to be a challenging topic. Gamification in programming learning has been found to increase students' interest, engagement and motivation in learning. However, the use of gamification also has limitations in terms of technical aspects, implementation and results. This research investigates the use of gamification in programming learning and various conclusions derived from the Systematic Literature Review approach. This study has the following problem statements: 1) the obstacles faced by students in learning programming; 2) the technical implementation of gamification, such as the technology, features and game aspects employed; and 3) the influence of gamification implementation on programming learning. The findings of this study help in determining whether the use of gamification through game features can help students overcome obstacles.**

***Index Terms*—Gamification, programming learning, systematic review, teaching-learning process, higher education.**

I. Introduction

Some students consider programming to be a challenging subject to study [1], [2]. While several studies have identified various issues with programming learning, the learning environment in programming classes influences students' motivation and performance in learning [3], [4]. Other issues that students face include conceptual understanding [5], code quality [6] and a tedious learning process [7], [8]. The problems that students encounter while learning programming have an impact on their motivation and performance [5]–[8].

Several studies have found that engaging learning can boost students' motivation and attention. Gamification provides a solution to this problem [9]–[11]. Gamification is the application of game mechanics and activities to an environment where the primary goal is not entertainment [12]. It has been used extensively in education with positive results [4], [11]–[14].

The adoption of game elements in serious contexts, such as business and education, is closely related to gamification implementation [15], [16]. According to Werbach and Hunter, the gamification model has three components: dynamics, mechanics and components [17]. The dynamics comprise the context in which gamification is developed. Mechanics is a dynamic activity, and the components are the objects or elements used in the mechanics to reward participants.

The dynamics component includes: 1) emotion, which is present when students receive feedback from the teacher; 2) narrative, which is a challenge framed in a story; 3) progression, which allows students to see their progress; and 4) social, which allows for teamwork. Mechanics comprises challenges and opportunities, while points, badges, avatars and leaderboards are among the components [11], [16], [18]–[20]. Table I shows how the three elements are organised.

Therefore, this research aims to explore various types of gamification implementation, the technology and features used and how they impact the problems that students face when learning programming. Programming learning is used not only for college-level learning but also for high-school-level learning. This investigation is therefore organised as follows: the literature review procedure, evaluation of the findings and drawing of conclusions.

TABLE I: Model of Gamification by Werbach and Hunter

Dynamics	*Mechanics*	*Components*
Emotion	*Challenges*	*Points*
Narrative	*Opportunities*	*Badges*
Progression		*Avatars*
Social		*Leaderboard*

II. Research Methodology

This study was carried out by conducting a literature review using a systematic literature review framework comprising three major stages: planning, conducting and reporting the review. The following eight steps are frequently used within the three main stages: 1) formulate the problem, 2) develop and validate the review protocol, 3) search the literature, 4) screen for inclusion, 5) assess quality, 6) extract data, 7) analyse and synthesise data, and 8) report findings. It is essential to remember that the first and second stages can be iterative [21]. Fig. 1 illustrates the process of conducting a systematic literature review.

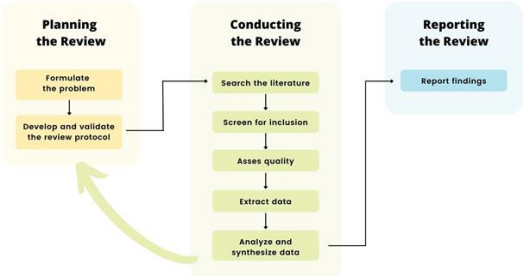

Fig. 1. Systematic literature review process.

The first step was to formulate the problem, which

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involved determining the research topic; in this case, the implementation of gamification in programming learning. The second step was to develop and validate the review protocol; this describes all elements of the review, such as the research objectives, research questions and strategies for data extraction, synthesis and reporting. This study aims to investigate and summarise the implementation of gamification, the technology and features used, and how they impact the problems students face in learning programming.

Based on these objectives, the following three research questions are posed: 1) What are the problems that students face in learning programming? 2) How are the technologies and features used in the application of gamification, including the applications used, the game elements included, the programming languages taught, etc.? 3) What is the impact of using gamification in learning; what are the advantages and disadvantages of using gamification in programming learning? Based on this, the data extraction, synthesis and reporting strategy was executed by creating a table with columns for the literature information, including the title, author, year, paper type, journal/proceeding/book title, research questions answered, findings and synthesis.

The third step comprised a review of literature titles using the keywords 'gamification' and 'programming'. Electronic databases including Scopus, ScienceDirect, ACM and ResearchGate were searched. The search using the pre-determined keywords returned a total of 41 journal/proceedings/book titles from the various databases (see Table II). The fourth stage entailed screening for inclusion by reviewing the abstracts from the literature to determine whether the articles could answer the research questions. Fifth, the quality was assessed by conducting a thorough review of the literature to determine whether it was appropriate for its findings and met the criteria for the most recent research published between 2018 and 2022.

Sixth, data were extracted from the literature by taking the findings of a more specific answer for each research question. The seventh stage consisted of an analysis and synthesis of the data by extracting the significance of the literature findings that would be used to answer the research questions. The responses were then organised into three separate tables based on the research questions. Finally, the findings were reported by writing up the synthesis results and the conclusions drawn from the findings.

TABLE II: NUMBER OF WORKS OF LITERATURE REVIEWED BY TYPE

Type of Publication	*Title of Journal/Proceedings/Book*	*Number of Articles*
Proceedings	IEEE Global Engineering Education Conference (EDUCON)	2
Book Chapter	Learning and Collaboration Technologies	1
Proceedings	ACM Conference on Innovation and Technology in Computer Science Education	1
Proceedings	International Conference on Multimedia Systems and Signal Processing	1
Proceedings	ACM Technical Symposium on Computer Science Education	2
Journal	MDPI Computers	1
Proceedings	IOP Conference Series: Materials Science and Engineering	2
Journal	Journal of Physics: Conference Series	4
Journal	Procedia Computer Science	2
Journal	I.J. Modern Education and Computer Science	1
Journal	MDPI Information	1
Proceedings	OASICS: OpenAccess Series in Informatics	1
Journal	Indonesian Journal of Electrical Engineering and Computer Science	1
Journal	Computers and Education: Artificial Intelligence	1
Journal	Computers & Graphics	1
Journal	E-Learning and Games	1
Proceedings	Systems and Information Sciences	1
Journal	Universal Access in the Information Society	1
Journal	ACM Transactions on Computing Education	1
Journal	International Journal of Electrical, Energy and Power System Engineering (IJEEPSE)	1
Proceedings	Hawaii International Conference on System Sciences	1
Journal	Journal of Game, Game Art and Gamification	1
Journal	International Journal of Modern Education	1
Proceedings	ASEE Virtual Annual Conference Content Access	1
Journal	Computer Applications in Engineering Education	1
Journal	The Challenges of the Digital Transformation in Education	1
Journal	PEOPLE: International Journal of Social Sciences	1
Proceedings	International Conference on Higher Education Advances	1
Proceedings	EdMedia + Innovate Learning	1
Journal	IJNMT (International Journal of New Media Technology)	1
Proceedings	International Conference on Information and Communication Technology (ICoICT)	1
Proceedings	Kolokium Pembentangan Kertas Penyelidikan Dan Inovasi	1
Proceedings	Australasian Computing Education Conference	1
	Total	**41**

III. FINDINGS AND DISCUSSION

The investigation yielded 41 articles that could potentially answer the research questions. The synthesis of the results identified 29 different types of gamification implementations in programming learning. This demonstrates that gamification is an intriguing topic for educational researchers interested in investigating the use of games to motivate and attract student involvement in learning [15]. As a result, for researchers interested in this field, the study provides an informative summary of the various gamification implementations carried out. In the discussion below, the findings are discussed in greater detail concerning each implementation and for each research question.

A. Problems Faced by Students in Learning Programming

A total of 21 out of the 41 articles were able to address the research question concerning the problems that students face when learning programming. For example, students struggle with the number of skills required to learn programming, such as problem-solving, writing code and complex and difficult-to-master algorithms [11]. Since many students struggle to learn these skills, programming learning is frequently characterised by frustration, high resignation rates and loss of interest and motivation [11], [14]. In contrast, the use of gamification elements in many studies increases student involvement in learning. Furthermore, proper gamification design in the learning system will improve student learning achievement [3].

Table III summarises the various problems that frequently occur in programming learning and the use of gamification as a solution to these problems.

TABLE III: PROGRAMMING LEARNING PROBLEMS SOLVED BY GAMIFICATION IMPLEMENTATION

Problem	Implementation	Articles
Lack of interest	Learning Model [14], Java Hero [22], Kahoot [23]	3
Low motivation	Learning Model [9], [14], Mobile Apps [7], [24], CLIS [5], UDPiler [25], LMS [26], SCoRe [27]	8
Difficulty in writing code	WOJ [6], Learning Model [28]	2
Difficulty in mastering programming concepts	Mobile Apps [7], CLIS [5], BattleWeb [29], LMS [26], Learning Model [30]	5
Tedious learning process	Mobile Apps [7], [8], CLIS [5], TED [31]	4
Difficulty in mastering support skills	Mobile Apps [7], Learn Your Way Out [11]	2
Limited learning resources	Mobile Apps [24]	1
Low engagement	Learning Model [9], Grasshopper [3], LMS [26], Mobile Apps [8], Moodle [18], SCoRe [27]	6
Missing an assignment	RunCode [32]	1
Considering the subject difficult	Learning Model [14], Learn Your Way Out [11], Daily Mission [33]	3

Table III reveals ten problems encountered by students while learning programming. These include a lack of interest in learning [14], [22], [23], low motivation [5], [7], [9], [14], [24]–[27], difficulty in writing code [6], [28], difficulty in mastering programming concepts [5], [7], [26], [29], [30], tedious learning process [5], [7], [8], [31], difficulty in mastering support skills [7], [11], limited learning resources [24], low engagement in learning [3], [8], [9], [18], [26], [27], missing a given assignment [32], and considering programming to be difficult [11], [14], [33].

Three main problems frequently arise among the ten identified: students have low motivation, have difficulty mastering programming concepts and are less involved in the learning process. To overcome the lack of student motivation, gamification is applied to the learning model [9], [14] and various applications are used such as mobile apps [7], [24], Children Learning in Science (CLIS) [5], UDPiler [25], LMS [26] and Student Code Review (SCoRe) [27]. Furthermore, difficulties in mastering programming concepts are overcome by implementing gamification using mobile apps [7], CLIS [5], BattleWeb [29], LMS [26] and a learning model [30]. Meanwhile, the problem of low student engagement in learning is solved by the learning model [9], Grasshopper [3], LMS [26], mobile apps [8], Moodle [18] and SCoRe [27].

The three most common problems are students' interest in learning, a tedious learning process and students' perception of programming as difficult. Problems concerning students' interest in learning are solved through the implementation of gamification in the learning model [14], Java Hero [22] and Kahoot [23]. In terms of the tedious learning process, gamification is implemented through mobile apps [7], [8], CLIS [5] and The Education District (TED) [31]. Finally, to overcome the problem of students who find programming difficult, gamification is applied through a learning model [14], Learn Your Way Out [11] and Daily Mission [33].

Finally, the following problems and remedies are also associated with learning programming: students find it difficult to write code, which is solved by Wasda Online Judge (WOJ) [6] and the learning model [28]; difficulties in mastering supporting skills are solved by mobile apps [7] and Learn Your Way Out [11]; limited learning resources are overcome through the use of mobile app solutions [24], and the problem of students not doing their assignments is solved by implementing gamification in RunCode [32]. The following section contains a more detailed discussion of the implementation of gamification.

B. Technology, Features and Game Components Used in the Implementation of Gamification

As previously explained, the implementation of gamification in programming learning varies from innovations in the learning model to the use of applications on various platforms. The measures taken often aim to attract the attention of students so that they can focus on what is being learned. As such, this constitutes a positive indication for the future in terms of improving students' engagement and motivation in learning programming [11].

The implementation of gamification is closely related to the use of game components in a serious activity [15]. However, not all game components in the three main elements of gamification (dynamics, mechanics and components) can be found in a single application. The exploration results indicate that several game components can be used to implement gamification. Table IV contains details of the implementation of gamification in

programming learning, starting from the language, technology, features and game components used according to student level.

Table IV indicates that gamification can be implemented through the innovation of learning models in the classroom [9], [14], [20], [29], [34], LMS [12], [26], web-based platforms [6], [11], [15], [16], [18], [23], [25], [27], [30], [32], [35]–[43], mobile applications [3], [7], [8], [22], [24], [44]–[47], educational games [5], [13], [48] and 3D virtual environments [31]. C and Java are the most commonly learned programming languages in the implementation of gamification. Meanwhile, the implementation of gamification is shown to be most useful for learning basic programming concepts at the high school and higher education levels.

In the innovation of learning models, gamification is implemented by adopting game concepts or applying the dynamics of games in class. In the preparation stage, students are divided into several groups and each group is given challenges to complete. Each challenge has a different level according to the difficulty of the learning material. After completing the challenges, the students receive rewards in the form of points or badges. Challenges can take the form of tournaments between teams to determine the winner. Components of games such as challenges, points, badges and leaderboards are probably also applied despite manual application.

Web-based platforms are the most frequently chosen means of gamification implementation by researchers. For this reason, the features vary and include 1) challenges in the form of written stories in Moodle, 2) an automatic assessment system in WOJ, Learn Your Way Out, 2TSW system, Daily Mission and Web-CAT, 3) options for elements of gamification that can be modified in PeerWise, 4) quizzes with many players in Kahoot, 5) the locking of subsequent materials before completing challenges in FGPE, 6) platforms to upload, perform and assess quest in Rimings, 7) a leaderboard displayed in the form of a graph in TST, 8) anonymous peer code review in SCoRe, and 9) a discussion forum in CyOURwAY. From the features, more types of game components are applied than learning model innovations. The components include challenges, points, badges, leaderboards, avatars, narrative, emotion, feedback and progression.

Gamification is also implemented using mobile applications. This type of implementation enables features such as 1) tutorials and simulations of code writing in C-Rocks, 2) quizzes to access next materials in Megie, 3) the use of attractive designs in Grasshopper, 4) markers that use augmented reality (AR) to control a character in CodAR, 5) the tracking and analysis of the student's attitude in each level, 6) points gained through a leaderboard in Fication, and 7) help in Java hero. The components of games found in these implementations are similar to those in learning model innovations, such as challenges, points, badges and leaderboards.

Next, gamification implementation is also found in educational games. The most attractive implementation emerges in the context of environmental awareness with features of industrial estate-building based on algorithms and related topics. Moreover, other features used in educational games include cases to solve in each level and supporting characters that provide clues to aid in completing challenges, as in CLIS. Challenges and points are the components of games used in this type of application.

Finally, an aspect that was scarcely seen in the present study concerns the implementation of gamification in a 3D virtual environment. The exploration results show that the features in this implementation comprise 3D elements to complete a task, namely building a castle. After building the castle, students are given the challenge to attack their opponent's castle by answering questions at its gate. Points are then awarded to the team that successfully seizes the opposing team's flag. It follows that the components of gamification implemented include challenges and points.

Across the five forms of implementation, challenges and points are the most frequently used game components. Challenges are given as tasks to complete, while points are awarded after completion of the given tasks [16]. The inclusion of these two components of games will ensure that students' attention is enhanced, thus hopefully improving their engagement and motivation in learning programming [11].

TABLE IV: TECHNOLOGY, FEATURES AND COMPONENTS OF GAME IN THE IMPLEMENTATION OF GAMIFICATION

Application	Language	Technology	Features	Components of Game	Student Level
Learning Model	C	Adopting concepts of video games, improving skills to change level	Surprise box to provide challenges and elimination tournaments to determine a winner	Leaderboard, points, badges	Higher Education
Moodle	OOP	A web platform	Provides challenges conveyed through stories to be completed in a team	Emotion, narrative, progression, challenges, points, badges, avatars, leaderboard	Higher Education
WOJ	C	A web-based (online) learning system with an extension of WOJS (WOJ Standings) that	Gives online assessments on code quality, ranking them by the highest score, and awards badges to the three students with the highest scores	Leaderboard, points, badges	Higher Education

		implements elements of gamification			
Mobile Apps	Python & C	A gamification-based mobile app architecture adopting an unsupervised learning algorithm to analyse students' behaviour	Provides programming concepts at various levels and gives assignments and quizzes. Students' behaviour is tracked and analysed at each level.	Challenges, points	Higher Education
PeerWise	Basic	An online learning device that collects questions and for which the elements of gamification can be modified	Provides questions with points rewards for correct answers. The results are authenticated through the Hexad survey to determine the types of users.	Challenges, leaderboard, points, badges	Higher Education
Mobile Game	JavaScript	An interactive mobile game developed by adopting contexts of gamification-based environmental awareness	Provides various algorithm topics as an industrial estate-building challenge. Points are added if players complete the challenge and are removed if they fail.	Challenges, points, badges	Higher Education
C-Rocks	C	A gamification-based Android application adopting the theories of constructivism, behaviourism and instructivism	Provides simulation, tutorial syntax, tasks and challenges, as well as assessment from C programming	Challenges, points	Higher Education
CodeToProtect	C++	An educational video game emphasising the use of C++ language with interesting plots	Features visual illustrations of instruction for each line of code to give a complete understanding; provides a set of tests to assess players' understanding and evaluate players, and provides interesting plots	Challenges, points	Higher Education
Learn Your Way Out	Java	A web game that develops the gamification approach using a player-centred, iterative, interdisciplinary and integrated framework	Provides online assessment on code quality and ranking by the highest score; awards badges to the three students with the highest scores	Challenges, rewards, progress	-
Kahoot	PHP	A web application used as a platform that enables many players to play a quiz game	Provides the tools to create a quiz, provides a page for invited players to answer a quiz and displays the points earned by players	Challenges, points, badges, leaderboard	Higher Education
CLIS	Basic	An educational game equipped with NPC characters to assist players in solving problems	Gives cases that must be solved in each level, supporting characters to give clues about how problems should be solved, and scores/points for successful problem-solving	Challenges, points	High School
FGPE (Framework for Gamified Programming Education)	Basic	Web-based programming learning with gamification	Provides both students and teachers with a complete ecosystem to learn programming; challenges to complete individually or collectively	Points, badges, leaderboard	-
Rimings	Basic	A gamification-based web application analysed using the Octalysis framework	Presents three types of users; provides a platform to upload, complete and assess quests according to the subject	Points, badges, avatars	Higher Education
Megie	Web Programming	A gamification-based mobile application, the development of which adopts Alessi and Trollip's learning model	Provides a course for registered users, materials and quizzes related to the topics of web programming. The next materials are unlocked after the completion of a quiz. Points are awarded.	Challenges, badges, points	Higher Education
Grasshopper	JavaScript	An open-access application based on	Provides various tasks and quizzes related to web programming with an attractive design	Challenges, points, badges	High School & Higher

		gamification			Education
2TSW	Basic	A web-based system with a gamified learning environment and automatic assessments	Provides tasks to complete, automatically displays an assessment of programs, and gives rewards after task completion	Badges, points, leaderboard, avatars	High School & Higher Education
CodAR	Basic	A mobile application that integrates the benefits of game-based learning, AR and GLA (Game Learning Analytics)	Presents characters that can move depending on the steps taken, provides a card that functions as a marker from AR to control the characters, and gives points as rewards	Challenges, points	Higher Education
LMS	Basic	Gamification-based LMS with OpenBadges to handle a mechanism for badges and SCORM in creating interactive contents	Provides interactive content, direction that explains tasks, feedback on the tasks, avatars, and characters to assist students	Challenges, points, badges, avatars	Higher Education
UDPiler	C	A gamification platform developed using the MDA (Mechanics-Dynamics-Aesthetics) framework	Provides programming challenges in the form of a compilation of C codes, course review and discussion forums, locks next materials and displays students' rank	Points, badges, leaderboard, keys	Higher Education
Daily Mission	Basic	An automatic assessment system with the additional design of daily missions	Provides different challenges in the form of daily missions by dividing them into small tasks; provides automatic assessment so that task results can be sent at any time for feedback	Challenges, points, feedback, rewards	Higher Education
Battle Web	Basic	Implementation of gamification techniques in class	Divides students into three groups, provides three challenge levels based on level of difficulty and gives markers that differ for each task completed	Challenges, badges	Higher Education
Web-CAT	Basic	An automatic assessment that integrates RPG, XP, levels and characters in feedback mechanisms	Provides tasks, gives XP and level up, and provides a character's page displaying evaluation results for completed tasks	Challenges, points, badges	Higher Education
CYourWay	C	A web-based gamification platform developed with ASP.NET and using SQL Server	Tasks with mixed difficulty; displays level status and points and badges gained; presents a discussion forum	Challenges, points, badges, avatars	Higher Education
Fication	Java	A mobile app with an e-learning model combined with gamification concepts	Provides materials and tutorials, allocates tasks in three different levels, badges are gained after task completion, displays points on a scoreboard and groups points in each level	Challenges, points, badges	Higher Education
TED	Basic	A 3D virtual environment for online learning	Provides elements to complete a task: building a castle, giving challenges to attack opponent's castles, giving points to the winning team	Challenges, points	Higher Education
RunCode	Basic	A learning platform with gamification concepts	Contains learning modules, tasks given in each module, and rewards after task completion	Challenges, points, badges	Higher Education
Java Hero	Java	A mobile application developed with the Octalysis gamification framework	Contains quests. Points are awarded following quest completion. Support is provided in the form of clues to complete the quest. Points are displayed on a leaderboard.	Challenges, points, leaderboard, avatars	Higher Education
TST	Python	A web-based gamification learning platform	Provides profile information in the form of tables, gives challenges in the form of tasks in every unit, displays a leaderboard in the form of graphics, awards badges for task completion	Challenges, leaderboard, badges	Higher Education
SCoRe	Basic	A web-based gamification platform to review anonymous peer codes	Permits students to send their code, anonymously manages code distribution, writes all sent reviews	Challenges, leaderboard, points, badges	Higher Education

C. The Impacts of Gamification on Learning

While the use of gamification has been found to show various positive impacts on students, it also has weaknesses. The positive and negative impacts of gamification are summarised in Table V. Here, the strengths of gamification implementation are classified into the following seven main advantages: 1) more interesting learning, 2) a better understanding of concepts, 3) enhancement of students' motivation, 4) better learning outcomes, 5) enhancement of students' participation in learning, 6) enhancement of students' programming skill and 7) fulfilment of students' need for learning resources. The most interesting insight is that game components such as points and leaderboards can enhance students' engagement in learning [27].

TABLE V: THE IMPACTS OF GAMIFICATION IMPLEMENTATION ON PROGRAMMING LEARNING

Application	Positive Impacts	Weaknesses
Learning Model	Learning becomes more engaging and motivating.	The use of a leaderboard contributes to increased levels of stress among low-ranking students.
Moodle	Teacher feedback and challenges help students build a deeper understanding of topics; leaderboards motivate students to compete with the opposing team.	Some students are less comfortable knowing that their score is displayed on a leaderboard. The application is less suitable for individual activities.
WOJ	A leaderboard using CC in a Software Engineering class motivates students so scores are not interrupted.	-
PeerWise	Students are motivated to learn through challenges to answer correctly and points rewards to win.	The gamification elements chosen by students are not proved to be connected to the classification of types of users.
C-Rocks	C-Rocks improves students' knowledge of C programming. This is proved by their log reports indicating an increase in knowledge scores.	Topic complexity affects students' understanding; the results of the study show that most students do not excel in topics with complicated syntax.
CodeToProtect	Most students are interested in learning C++ programming using CodeToProtect.	-
Learn Your Way Out	The game elements used provide positive motivation for users to learn basic Java topics.	Users have no urgency to commit to game activities. Moreover, it remains a simple game and has spaces that require further improvement.
Kahoot	Most students recommend Kahoot to other teachers because it has a positive impact on their motivation and engagement in learning.	Insufficient time is given to answer questions.
Mobile Apps	The need for students' learning resources is met. The application is proved to be feasible as a learning medium.	It is accessible only by phone.
CLIS	Students respond positively to the implementation of learning; the use of CLIS positively impacts the development of students' abilities.	-
Rimings	Rimings helps motivate students to learn programming and achieve excellent scores.	-
Megie	Magie deserves to be used in Web Programming learning since it is proven to be effective in improving students' learning outcomes. The combination of gamification and attractive mobile learning enables students to become more independent in learning.	-
Grasshopper	Grasshopper is accepted by users and grabs students' attention in learning.	Incomplete programming language materials for learning web programming.
2STW	Useful for enhancing students' programming skills. Many students are seen to engage in programming problem-solving.	-
CodAR	Most students enjoy the new experience of using AR and therefore CodAR can help improve their basic programming skills.	The AR markers are difficult to move when a low-quality camera is used.
UDPiler	Gamification is considered to be effective in improving the C programming learning process so students achieve better scores.	-
Daily Mission	Daily Mission is suitable for project-based tasks. Its feedback feature improves students' insights so they can gain more understanding in learning.	It has not yet been proved to be capable of assessing change in students' programming habits and achievement.
BattleWeb	BattleWeb helps captivate students' interest and improve their motivation and performance in learning web design.	It can only be played on a personal computer.

CYourWay	Student satisfaction is positively correlated with student intrinsic motivation.	Time does not affect students' efforts, satisfaction and intrinsic motivation.
Fication	The application has excellent usability so that e-learning can be applied in mobile learning.	The application inadequately motivates students to complete all levels. Therefore, it requires a redesign by adding profiles, achievements, rewards and status.
TED	Most students are satisfied and they like the dynamics of the learning activities. This improves students' engagement in learning.	Further studies are required to evaluate time and anticipate problems and solutions.
RunCode	The application improves students' engagement in learning. It is proved by the increased number of students completing tasks.	-
Java Hero	The implementation of gamification can improve students' motivation and interest in learning Java programming.	The application is not widely known.
TST	More students finish tasks in earlier weeks.	A decline in the number of students submitting tasks as there is no requirement to complete tasks after the end of the course.
SCoRe	Points and leaderboards can improve students' engagement in giving reviews.	Bar energy does not significantly change students' attitudes in providing reviews at the end.

The implementation of gamification therefore has weaknesses in terms of technical aspects, execution and results. Technical weaknesses include the short time available in which to complete challenges, application access limited to one device (mobile phone or PC), difficulty in scanning the AR marker due to low camera quality, lesser-known applications and the language barrier (applications are in English only). Meanwhile, in execution, weaknesses include the use of leaderboards, which low-ranking students are less comfortable with and find stressful. Additionally, the complexity of the learned topics affects students' understanding. Greater topic complexity leads to more students being unable to understand the topics [44]. As such, the implementation of gamification has a lower impact on highly complex programming learning.

In terms of results, the implementation of gamification in Learn Your Way Out indicates that: 1) users have no urgency to commit to game activities, and 2) it remains a simple game with spaces requiring further improvement. In addition, further studies need to be conducted to evaluate the time taken and anticipate problems and solutions in the implementation of gamification in TED. Finally, the use of Daily Mission has not been proved suitable for assessing the change in students' programming habits and achievements. For that reason, in the implementation of gamification, it is important to prepare solutions for the worst-case scenario that may arise during programming learning.

IV. Conclusion

The present study details the results of an exploration of the implementation of gamification in programming learning by reviewing 41 articles and related topics. It has shown that the problems being addressed in the implementation of gamification relate to students' lack of interest, motivation and engagement in learning. The problems arise due to various factors, such as uninteresting learning, limited learning resources, difficulty in mastering concepts and supporting skills, and difficulty producing good-quality codes.

The exploration results indicate that gamification in programming learning has been commonly implemented in learning model innovations, the use of mobile apps, web-based problems, educational games and even 3D virtual environments. Gamification is mostly implemented in basic programming topics using programming languages such as C and Java.

Various features are used in the process of gamification implementation. Challenges and rewards are clear features in each implementation. The challenges can be tasks, quests, quizzes and missions. Meanwhile, rewards can be points or badges. In addition, the locking of subsequent content prior to task completion is found in the implementation of gamification. For that reason, challenges and points are the most frequently used components of games. Other common game components include badges, leaderboards, avatars and feedback. Points and leaderboards are considered capable of improving students' engagement in learning. However, their use leads to stress and a decline in the motivation of low-ranking students.

Most of the results for the implementation of gamification show a positive impact in terms of improving students' interest, engagement and motivation in programming learning based on the main problems they encounter. However, it is important to highlight that the implementation of gamification also has weaknesses in technical aspects, execution and results. Additionally, the implementation of gamification has less impact on highly complex programming learning.

Conflict Of Interest

The authors declare no conflict of interest.

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References

[1] C. Daly, "Roboprof and an introductory computer programming course," *SIGCSE Bull. (Association Comput. Mach. Spec. Interes. Gr.*

Comput. Sci. Educ., vol. 31, no. 3, pp. 155–158, 1999, doi: 10.1145/384267.305904.
[2] T. Jenkins, "On the difficulty of learning to program," *3rd Annu. LTSN-ICS Conf. Univ.*, pp. 53–58, 2002.
[3] R. Nuravianty, H. B. Santoso, and K. Junus, "Usability evaluation of a gamification-based programming learning platform : Grasshopper," *J. Phys. Conf. Ser.*, 2021, doi: 10.1088/1742-6596/1898/1/012020.
[4] F. A. Pratama, R. M. Silitonga, and Y. Jou, "Rimigs : The impact of gamification on students ' motivation and performance in programming class," vol. 24, no. 3, pp. 1789–1795, 2022, doi: 10.11591/ijeecs.v24.i3.pp1789-1795.
[5] H. W. Prabawa, H. Sutarno, J. Kusnendar, and F. Rahmah, "Learning basic programming using CLIS through gamification," *IOP Conf. Ser. J. Phys.*, 2018.
[6] R. Kasahara, K. Sakamoto, H. Washizaki, and Y. Fukazawa, "Applying gamification to motivate students to write high-uality code in programming assignments," in *Proc. 2019 ACM Conf. Innov. Technol. Comput. Sci. Educ.*, pp. 92–98, 2019.
[7] L. M. Padirayon, "The designed gamification application architecture and elements for a C # programming course," in *Proc. 2019 4th Int. Conf. Multimed. Syst. Signal Process.*, pp. 67–72, 2019.
[8] M. Priyaadharshini, N. Nathamayil, R. Dakshina, S. Sandhya, and B. S. R, "Learning analytics: Game-based learning for programming course in higher education," *Procedia Comput. Sci.*, vol. 00, no. 2019, pp. 468–472, 2020, doi: 10.1016/j.procs.2020.05.143.
[9] D. P. Y. Ardiana and L. H. Loekito, "Gamification design to improve student motivation on learning object-oriented programming," *J. Phys. Conf. Ser.*, 2020, doi: 10.1088/1742-6596/1516/1/012041.
[10] T. D. Chifamba and Y. M. Motara, "Gamification of functional programming," *IEEE*, 2021.
[11] N. L. Mingoca and E. L. R. Sala, "Design and development of learn your way out: A gamified content for basic java computer programming," *Procedia Comput. Sci.*, vol. 161, pp. 1011–1018, 2019, doi: 10.1016/j.procs.2019.11.211.
[12] D. F. L. Buitrago *et al.*, "Gamification strategies for an introductory algorithms and programming course," *Edutainment 2018 e-Learning Games*, vol. 2, pp. 84–87, 2019, doi: 10.1007/978-3-030-23712-7.
[13] M. M. Ariffin, N. M. Aszemi, and M. S. Mazlan, "CodeToProtect © : C ++ programming language video game for teaching higher education learners," *J. Phys. Conf. Ser.*, 2021, doi: 10.1088/1742-6596/1874/1/012064.
[14] J. Figueiredo and F. J. García-Peñalvo, "Increasing student motivation in computer programming with gamification," *IEEE Glob. Eng. Educ. Conf.*, no. April, pp. 997–1000, 2020.
[15] I. Ouahbi, H. Darhmaou, and F. Kaddari, "Gamification approach in teaching web programming courses in PHP : Use of KAHOOT application," *I.J. Mod. Educ. Comput. Sci.*, no. April, pp. 33–39, 2021, doi: 10.5815/ijmecs.2021.02.04.
[16] A. Rojas and E. G. Rincón-Flores, "Gamification as learning scenario in programming course of higher education," *Learn. Collab. Technol. Learn. Teach.*, no. June, 2018, doi: 10.1007/978-3-319-91152-6.
[17] K. Werbach and D. Hunter, *For the Win: How Game Thinking Can Revolutionize Your Business*, Wharton Digital Press, 2012.
[18] A. Rojas-López, E. G. Rincón-Flores, J. Mena, F. J. García-Peñalvo, and M. S. Ramírez-Montoya, "Engagement in the course of programming in higher education through the use of gamification," *Univers. Access Inf. Soc.*, no. 0123456789, 2019, doi: 10.1007/s10209-019-00680-z.
[19] J. Swacha, R. Queirós, J. C. Paiva, and J. P. Leal, "Defining requirements for a gamified programming exercises format," *Procedia Comput. Sci.*, vol. 00, pp. 2502–2511, 2019, doi: 10.1016/j.procs.2019.09.425.
[20] Winanti, B. S. Abbas, W. Suparta, Y. Heryadi, A. Trisetyarso, and F. L. Gaol, "Gamification framework for programming course in higher education," *J. Game, Game Art Gamification*, vol. 05, no. 02, pp. 2018–2021, 2020.
[21] Y. Xiao and M. Watson, "Guidance on conducting a systematic literature review," *J. Plan. Educ. Res.*, vol. 39, no. 1, pp. 93–112, 2019, doi: 10.1177/0739456X17723971.
[22] L. Christopher and A. Waworuntu, "Java programming language learning application based on octalysis gamification framework," *IJNMT (International J. New Media Technol.*, vol. 8, no. 1, pp. 65–69, 2021.
[23] S. Z. binti Wahid, "The effectiveness of gamification in improving student performance for programming lesson the effectiveness of gamification in improving student performance for programming lesson," *Kolok. Pembentangan Kertas Penyelid. Dan Inov.*, no. April, 2019.
[24] W. N. Hidayat, A. Fitranti, A. F. Firdaus, C. D. I. Kartikasari, and T. A. Sutikno, "Gamification based mobile application as learning media innovation for basic programming lessons," *IOP Conf. Ser. Mater. Sci. Eng.*, 2020, doi: 10.1088/1757-899X/732/1/012113.
[25] J. F. B. Marín, J. Cruz-lemus, and M. Genero, "An empirical investigation on the benefits of gamification," *ACM Trans. Comput. Educ.*, vol. 19, no. 1, pp. 1–22, 2018.
[26] L. S. Jen and S. H. M. Said, "Application of gamification in introduction to programming: A case study," *PEOPLE Int. J. Soc. Sci.*, vol. 4, no. 3, pp. 845–864, 2019.
[27] T. D. Indriasari, A. Luxton-reilly, and P. Denny, "Improving student peer code review using gamification," *Australas. Comput. Educ. Conf.*, pp. 80–87, 2021.
[28] R. R. Andhi, E. Susilo, and S. Nasution, "Improving student' s coding skill with gamification website-based program," *Int. J. Electr. Energy Power Syst. Eng.*, vol. 4, no. 3, pp. 191–195, 2021.
[29] Z. Ngadengon, F. Rahmat, and N. S. M. Zawawi, "Keberkesanan gamifikasi dalam pembelajaran teknologi rekabentuk web," *Int. J. Mod. Educ.*, vol. 3, no. 10, pp. 48–61, 2021, doi: 10.35631/IJMOE.310004.
[30] Y. A. Permana, D. S. Kusumo, and D. Nurjanah, "Gamification for learning basic algorithm," *Int. Conf. Inf. Commun. Technol.*, no. October, 2018, doi: 10.1109/ICoICT.2018.8528723.
[31] I. Rodríguez, M. Salamó, and A. Puig, "Design and evaluation of gamification experiences in computer science studies," *Int. Conf. High. Educ. Adv.*, vol. 10, pp. 1137–1145, 2020.
[32] M. Pankiewicz, "Move in the right direction: Impacting students' engagement with gamification in a programming course move in the right direction : Impacting students' engagement with gamification in a programming course," *Conf. EdMedia + Innov. Learn. 2020*, no. July, 2020.
[33] S. H. Edwards and A. B. Goldman, "Using the 'daily missions' gamification strategy to promote incremental progress on programming assignments," *Hawaii Int. Conf. Syst. Sci.*, pp. 1236–1245, 2020.
[34] M. Carreño-León, A. Sandoval-Bringas, F. Álvarez-Rodríguez, and Y. Camacho-González, "Gamification technique for teaching programming," *IEEE Glob. Eng. Educ. Conf.*, pp. 2009–2014, 2018.
[35] M. Rogers, W. Yao, A. Luxton-reilly, D. Lottridge, and P. Denny, "Exploring personalization of gamification in an introductory programming course," *Proc. 52nd ACM Tech. Symp. Comput. Sci. Educ.*, pp. 1121–1127, 2021.
[36] J. C. Paiva, R. Queirós, J. P. Leal, J. Swacha, and F. Miernik, "Managing gamified programming courses with the FGPE platform," *MDPI Inf. 2022*, pp. 1–16, 2022.
[37] J. C. Paiva, R. Queirós, J. P. Leal, J. Swacha, and F. Miernik, "An open-source gamified programming learning environment," vol. 91, no. 5. Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl Publishing, Germany, pp. 5:1-5:0, 2021, doi: 10.4230/OASIcs.ICPEC.2021.5.
[38] F. A. Pratama, R. M. Silitonga, and Y. Jou, "Rimigs: The impact of gamification on students' motivation and performance in programming class," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 24, no. 3, pp. 1789–1795, 2022, doi: 10.11591/ijeecs.v24.i3.pp1789-1795.
[39] G. Polito and M. Temperini, "A gamified web based system for computer programming learning," *Comput. Educ. Artif. Intell.*, vol. 2, p. 100029, 2021, doi: 10.1016/j.caeai.2021.100029.
[40] J. Llerena-Izquierdo and J. Idrovo-Llaguno, *Introducing Gamification to Improve the Evaluation Process of Programing Courses at the Salesian Polytechnic University (Guayaquil, Ecuador)*, 2020.
[41] Z. Li and S. H. Edwards, "Integrating role-playing gamification into programming activities to increase student engagement integrating role-playing gamification into programming activities to increase student engagement," *ASEE Virtual Annu. Conf. Content Access*, 2020.
[42] M. Tasadduq, M. S. Khan, R. M. A. Nawab, M. H. Jamal, and M. T. Chaudhry, "Exploring the effects of gamification on students with rote learning background while learning computer programming," *Comput. Appl. Eng. Educ.*, no. January, 2021, doi: 10.1002/cae.22428.
[43] R. G. de Pontes, D. D. S. Guerrero, and J. C. A. de Figueiredo, "Analyzing gamification impact on a mastery learning introductory programming course," *ACM Tech. Symp. Comput. Sci. Educ.*, pp. 400–406, 2019.
[44] J. A. Talingdan and C. R. Llanda, "Assessment of the effectiveness of learning theories using gamified android app in teaching C programming," *IOP Conf. Ser. Mater. Sci. Eng.*, 2019, doi: 10.1088/1757-899X/482/1/012030.
[45] S. Pambudi, T. Sukardiyono, and H. D. Surjono, "The development of mobile gamification learning application for web programming learning," *J. Phys. Conf. Ser.*, 2018, doi: 10.1088/1742-6596/1140/1/012046.

[46] V. Sharma, K. K. Bhagat, H.-H. Huang, and N.-S. Chen, "The design and evaluation of an ar-based serious game to teach programming," *Comput. Graph.*, vol. 103, pp. 1–18, 2022, doi: 10.1016/j.cag.2022.01.002.
[47] V. Tundjungsari, "Mobile learning design using gami fi cation for teaching and learning in algorithms and programming language," *Challenges Digit. Transform. Educ.*, pp. 650–661, 2020, doi: 10.1007/978-3-030-11932-4.
[48] R. Maskeliunas, A. Kulikajevas, T. Blažauskas, R. Damaševi˘cius, and J. Swacha, "An interactive serious mobile game for supporting the learning of programming in javascript in the context of eco-friendly city management," *MDPI Comput. 2020*, 2020.

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