SCIENTIFIC CULTURE

www.sci-cult.com

SCIENTIFIC CULTURE, Vol. 12, No. 2.1, (2026), pp. 3389-3403
Open Access. Online & Print

DOI: 10.5281/zenodo.19985561

LITERATURE REVIEW ON AI-DRIVEN PERSONALIZED LEARNING AND GAMIFICATION IN PROGRAMMING EDUCATION

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Received: 11/12/2025
Accepted: 02/02/2026

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ABSTRACT

Programming education has become vital in university curricula, providing students with critical thinking and problem-solving skills essential for innovation and adapting to new technologies. However, the abstract nature of programming concepts can lead to a lack of motivation among students, making it challenging to learn effectively. Gamification has emerged as an effective solution to enhance student motivation and engagement, while AI-driven personalized learning techniques offer the potential to further amplify these benefits. This literature review examines related works on AI-driven personalized learning and gamification in programming education. We analyze various techniques and methods introduced in the field, along with performance metrics used to assess their effectiveness. We identify potential future directions and open problems based on our findings, aiming to guide further research and implementation strategies in this area.

KEYWORDS: AI, Gamification, Personalized Learning, Programming Education.

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1. INTRODUCTION

Nowadays, programming learning is crucial in university education. It equips students with critical thinking skills and practical knowledge [31]. These skills are needed to innovate and solve complex problems [4]. Moreover, it helps students adapt to new tools and languages, and hence makes them more flexible and adaptable in their career paths [11, 41]. However, some students may lack motivation and find learning programming excessively tough and challenging, due to its cryptic and abstract concepts [22, 34].

Therefore, students seek innovative approaches and methods to study programming that convert difficult concepts into understandable information and practical tasks, where instructors should incorporate these methods into their teaching to enhance the learning experience and engagement [40]. + One of this innovative approach is the serious gamification [7, 9].

It consists of using game tools to motivate students and assist teachers during the programming courses. Recently, the rapid advancement of web technologies and the widespread adoption of devices, e.g., tablets, smartphones, and laptops have significantly facilitated the integration of digital games into the educational framework. As a result, an increasing number of instructors have adopted the gamification approach to boost students' motivation, interest in learning, and academic achievement.

Consequently, gamification has been frequently employed across a diverse range of learning fields, enhancing engagement and retention [14, 51]. For instance, in the realm of artificial intelligence (AI), gamified approaches have proven effective in making complex concepts more accessible to learners [16, 19]. Similarly, in information technology (IT), gamification strategies have been used to motivate students and facilitate hands-on learning experiences [13, 43].

The integration of gamification in science technology engineering and mathematics (STEM) fields has also shown promise in fostering critical thinking and problem-solving skills [21, 24, 42].

In health education, gamification techniques are increasingly utilized to prepare students for real-world challenges in the medical field [12, 37, 47]. Moreover, in subjects such as ecology, and chemistry, gamification has been embraced to create interactive and motivating learning environments [44, 50]. History education has also benefited from these methods, engaging students in immersive learning experiences [27].

Additionally, gamification has been applied in emerging areas like blockchain technology [49], digital logic [18], and even soft skills development [1]. Furthermore, in the field of cybersecurity, gamification plays a crucial role in preparing students for the complexities of the digital system security [53].

In addition to the gamification approach, the AI and personalized learning have been recently proposed and deployed as promising solutions to further increase the effectiveness of gamification in many learning fields, including programming education [20, 35].

More specifically, this may involve data analysis, AI, and machine learning models in order to understand students' strengths, weaknesses, and learning styles [17, 28, 33]. Based on that, adaptive gaming elements can be designed and deployed to create more immersive and dynamic learning environments.

In this context, Feedback mechanisms has a significant role in the continued evolution of personalized gamified learning experiences [6]. In particular, it can deploy performance metrics, progress monitoring, and real-time feedback on coding exercises so that students can track their progress and adjust their learning strategies accordingly [26].

Overall, the integration of AI, personalized learning with gamification in programming education presents a promising approach to increase student's motivation, making learning more engaging, effective, and accessible for learners of all backgrounds and skill levels [5, 54].

In the literature, various review papers have (partially) addressed this specific topic. These related works have been presented and detailed in Section 2, where the relevant main findings, advantages, and limitations are listed.

As detailed in this section, and to the best of our knowledge having reviewed relevant and seminal literature in the field, a literature review on AI-driven personalized learning and gamification in programming education has not been presented in the literature yet.

1.1. Contributions

In light of the presented related works, this paper's contributions can be outlined as follows:

- The related review works in the literature are presented and detailed, where the main findings, the advantages, and the limitations are investigated.
- The gamification elements and techniques that have been used in programming education have been presented, along with the corresponding evaluation techniques and metrics.

- The AI and personalized techniques and methods are presented and investigated, in order to evaluate its role in boosting the benefits of using gamification in programming learning.
- A comprehensive list of open problems and challenges, as well as future research direction and their potential impacts, within the topic of AI-driven personalized learning and gamification in programming education has been presented.

1.2. Paper Organization

The remainder of this paper is organized as follows: First, Section 2 introduces the related works that review (part of) the topic of AI-driven personalized learning and gamification in programming education. Then, the used review method is presented in Section 3. Section 4 presents and details the relevant research attempts to the considered topic. Then, the corresponding open problems and challenges are listed in Section 5. Accordingly, we present, in Section 6, relevant future directions. Finally, conclusions are drawn in Section 7.

2. RELATED WORKS

The aim of this section is to present and discuss the main related works in the literature that review the topic of AI-driven personalized learning and gamification in programming education. To this end, we present in Table 1 different related works, as well as the relevant main findings, advantages, and limitations.

A review on AI-supported tutoring approaches for learning programming has been presented in [25]. This review has investigated various AI-based methods for learning programming, concluding that the feedback-based approach stands out as the most deployed in the literature. This approach is supported by AI techniques to identify the student's intention. For instance, it analyses how students tackle problems within the feedback-based learning method.

Although this review presents important insights into AI-based programming learning techniques, it overlooks the potential impact of gamification and personalized learning tools.

The authors in [3] have presented a literature review on gamification in online collaborative learning for programming courses. This work provides an overview of the methods by which gamification embedded in online collaborative learning can improve participation rates among students who are unfamiliar with programming.

The main findings of this literature review include the essential factors that are important for programming students to participate in online collaborative learning, gathering game components that are incorporated into online collaborative learning to motivate students to participate, and suggesting appropriate gamification techniques for programming courses.

In [10], a literature review on student modelling for personalized education has been presented. The aim of this review is to answer three main questions: what to model?, how to model ? And why to model?.

To answer these questions, the authors have presented and detailed comparative tables of a 10-year review study in student modelling. This work offers a useful guide for selecting the appropriate techniques to employ in designing a student model for a personalized tutoring system.

In [39], a review on gamification for learning fundamental programming has been presented. This review focuses on three main components that have been introduced in the literature to develop an interactive game, named Mechanics, Dynamics, Aesthetics. Furthermore, it has presented a set of evaluation techniques that can be used to assess the performances and the effectiveness of the considered gamification methods in learning fundamental programming. Literature Review on AI-Driven Personalized Learning and Gamification in Programming Education.

Based on that, the authors have identified the loopholes in the existing literature on gamification for learning fundamental programming. Accordingly, they have listed several unresolved issues within this domain, as well as some recommendations for potential future contributions.

In the same context, the authors in [32] have presented another literature review, where gamification has proven to be one of the creative approaches that is able to enhance student's motivation and learning engagement. This review has classified the introduced gamification applications and has provided valuable insights and perspectives on gamification for programming language learning. In particular, the majority of gamification applications have been designed for general programming language, where Gamification is an extremely successful method to get students interested in and enjoying learning particular courses or subjects.

In [30], the authors have presented a detailed literature review on the implementation of gamification in programming learning. First, they have listed the main challenges faced by students when studying programming. Subsequently, they have detailed the technical implementation of gamification, including the required features, the

Table 1. Related Works (Part 1)

Reference	Year	Gamification	AI	PL	Main Findings	Advantages & Limitations
[25]	2013	✗	✓	✗	• Provides a review of AI-based methods for teaching programming.	+ Offers valuable insights into AI-based programming education techniques. – Does not address the potential role of gamification or personalized learning tools.
[3]	2015	✓	✗	✗	• Identifies motivational factors influencing programming students in online collaborative learning. • Examines game elements integrated into collaborative learning environments. • Discusses potential gamification techniques for programming courses.	+ Provides detailed insights into gamification strategies for programming education. – Does not consider AI-driven or personalized learning approaches.
[10]	2015	✗	✗	✓	• Reviews techniques for designing student models in personalized tutoring systems.	+ Thoroughly discusses student modeling approaches for personalized tutoring systems. – Omits gamification and AI-based enhancements.
[39]	2019	✓	✗	✗	• Reviews evaluation methods for assessing gamification effectiveness. • Identifies gaps in the literature on gamification for fundamental programming education. • Highlights unresolved research challenges.	+ Clearly identifies research gaps and limitations in gamification for programming education. – Does not explore integration with AI or personalized learning tools.
[32]	2020	✓	✗	✗	• Classifies gamification applications. • Analyzes the impact of gamification on student motivation and engagement.	+ Provides a comprehensive classification of gamification applications. – Does not incorporate AI or personalized learning perspectives.
AI: Artificial Intelligence, PL: Personalized Learning						

Table 1. Related Works (Part 2)

Reference	Year	Gamification	AI	PL	Main Findings	Advantages & Limitations
[30]	2020	✓	✗	✗	• Difficulties that students face when learning programming. • The used features, technology, and game elements in the implementation of gamification applications. • The gamification's effects on programming learning.	+ The review elaborates on the challenges students encounter while learning programming. – The AI and the personalized learning tools have not been considered.
[23]	2022	✓	✗	✗	• The main addressed gamification elements in programming education. • The points-based method is the most deployed game element in the literature.	+ Provides detailed insights into gamification strategies for programming education. – Does not consider AI-driven or personalized learning approaches.
[52]	2022	✓	✗	✗	• The effectiveness of gamification techniques and applications in programming learning, regarding the students' academic achievement, cognitive load, motivation, and thinking skills.	+ The paper details various gamification techniques for programming courses, along with the relevant evaluation techniques. – The use of AI and personalized learning tools has been disregarded.
[45]	2023	✓	✗	✗	• The key problems that gamification intended to solve. • The main used gamification elements.	+ The paper outlines the main issues that gamification aims to solve. – The AI and the personalized learning tools have not been considered.
[20]	2023	✓	✓	✓	• Personalized gamification is an efficient approach to enhancing the motivation, engagement, and learning outcomes of programming courses' students..	+ This work is considering all the elements of the addressed topic, i.e., gamification, AI, and personalized learning. – It is more of a systematic review than a literature review that details the related technical contributions to this topic.
[38]	2024	✗	✓	✗	• Teachers play a crucial role in guiding students to effectively use AI tools in their studies.	+ Investigating the roles of teachers in AI-based programming education. – The gamification and the personalized learning tools have not been considered.
AI: Artificial Intelligence, PL: Personalized Learning						

relevant technology, and the used game elements. Then, the impacts of gamification on programming learning have been discussed.

A systematic literature review on gamification in computer programming education have been presented in [23]. In this review, the authors have investigated different related works and have identified the main addressed gamification elements in computer programming learning. According to this review, the points-based method is the most deployed game element in the literature.

In [52], drawing from a meta-analysis of 21 empirical studies published within the past decade, the authors have examined the effectiveness of gamification in programming learning. To this end, the authors have investigated the impacts of various related sides to gamification on students' academic achievement, cognitive load, motivation, and thinking skills. The main considered sides are the types of game, gamification applications, pedagogical agents, programming types, and schooling levels.

The results of this investigation present many important insights:

- Gamification has significant impact on students' motivation, with academic achievement ranking next, while having the least influence on students' cognitive load.

- For the types of game, the reasoning strategy game proves most effective in enhancing academic achievement, whereas the puzzle game is particularly effective in boosting motivation.

- Regarding the gamification application, games used as competitive mechanisms have the most significant impact on students' thinking skills and motivation. Conversely, when games are integrated as instructional tools or student assignments, their effects are primarily reflected in academic achievement.

Another literature review has been presented in [45], where the authors have presented and investigated experimental works that gamified teaching programming language in higher education to boost students' engagement and motivation.

In this work the authors analysed papers from 2018-2022 the conducted investigation was based on three main questions;

i) What issues is gamification designed to address? ii) How were the study results evaluated? iii) What types of gamification mechanics were implemented?

Accordingly, this literature review has identified the key points that gamification intended to improve, e.g., teaching methods, psychological and social effects, and study methods. In addition, the review has detailed the main used gamification elements, i.e., Points, Badges and Leaderboard (PBL).

Different from the previous literature review, the authors in [20] have presented a systematic literature review on personalization, cognition, and gamification-based programming language learning. The main findings of this review confirm the efficiency of personalized gamification in enhancing the motivation, engagement, and learning outcomes of programming courses' students.

It is worth mentioning that this work presents a systematic review more than a literature review, where 81 studies were analysed and investigated. In particular, it has been shown that the effectiveness of personalized gamification can vary depending on several factors. These include the type of used gamification elements, the individual characteristics of the learners involved, and the degree of personalization.

In [38], a review on AI tool usage in programming course has been presented. This study investigates the use of AI in university-level teaching, particularly emphasizing its application in programming learning. This investigation highlights the crucial role of teachers to guide the students in order to effectively use AI tools in their studies. As presented and detailed in this section, a consistent review on AI-driven personalized learning and gamification in programming education has not been presented in the literature yet.

In light of this, this paper provides a detailed literature review on this topic, using a 10 steps literature review method that is presented and detailed in the following section.

3. REVIEW METHOD

As presented in Fig. 1, the used literature review method consists of 10 steps:

Step 1 - Define the Main Topic: The first step consists of identifying the main topic of the paper, which revolves around four main axes: AI, personalized learning, gamification, and programming education.

Step 2 - Conduct a Comprehensive Literature Search: It involves collecting a broad range of relevant sources using keywords related to AI, personalized learning, gamification, and programming education.

Step 3 - Select and Evaluate Sources: In this step, only credible and reliable sources based on publication quality and research rigor have been considered.

Step 4 - Organize The Literature: The selected sources/ works have been organized in this step, chronologically, thematically, and methodologically.

Step 5 - Read and Analyse: For each related work, the corresponding details, advantages and

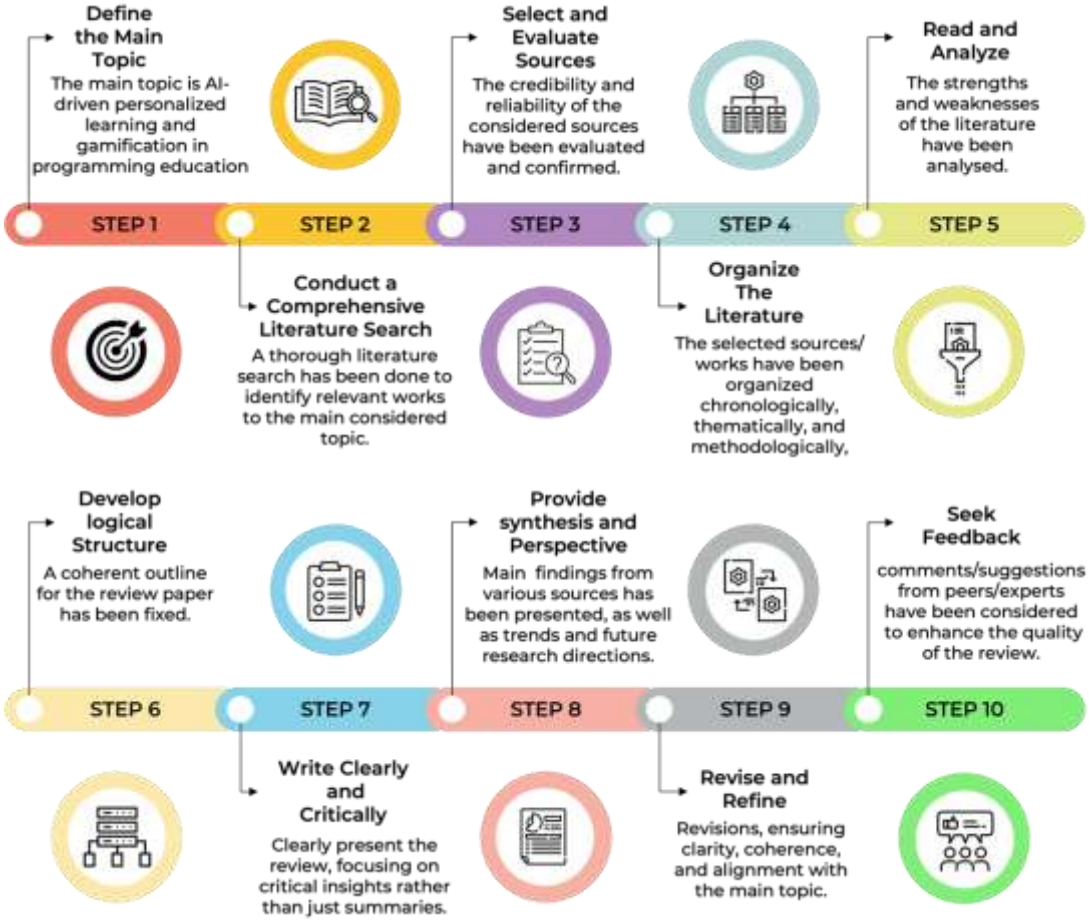

Fig. 1. The considered method of literature review on AI-driven personalized learning and gamification in programming education.

limitations have been investigated in this step.

Step 6 - Develop logical Structure: In this step, a coherent outline for the review has been fixed, including the related works, the relevant research attempts, the corresponding open problems and challenges, as well as relevant future directions.

Step 7 - Write Clearly and Critically: This step consists of presenting the relevant details and analysis in a clear, precise, and engaging manner, providing critical insights rather than just summaries.

Step 8 - Provide synthesis and Perspective: It aims at offering a comprehensive view, by integrating findings from various sources, highlighting trends and future research directions.

Step 9 - Revise and Refine: This step consists of revisions, ensuring clarity, coherence, and alignment with the main topic and objectives.

Step 10 - Seek Feedback: Finally, comments/suggestions from peers and experts have been considered to enhance the quality of the review.

4. RELATED RESEARCH ATTEMPTS

To the best of our knowledge, few research attempts have specifically addressed the topic of AI-driven personalized learning and gamification in programming education. In this section, we detail and investigate these related works, where we present in Table 2, the corresponding approach, technique, advantages, and limitations, as well as the evaluation metrics to assess the performances of the proposed solutions.

In [48], the authors have presented collaboration and fuzzy-modelled personalization for mobile game-based learning in higher education. In this work, the authors have investigated how game-based mobile learning can be used in higher education. To this end, they have designed and implemented Quiz Time! an intelligent mobile game-based learning app designed to assess and enhance learners' understanding of the C Sharp programming language.

Table 2. Summary of related works to the topic of AI-driven personalized learning and gamification in programming education (Part 1)

					Evaluation Metrics			
Refs.	**Year**	**Approach**	**Technique/Method**	**Advantages & limitations**	**M1**	**M2**	**M3**	**M4**
[48]	2020	Recommender System	A vectorial- based recommendation module and fuzzy logic	+ The use of recommender system and fuzzy logic offer efficient application of personalized gamification. + The application was tested in a university for one semester by students and computer science experts using statistical hypothesis testing. – The student modeling aspect is not addressed. – The introduced application does not incorporate thinking skills and cognitive load metrics for evaluation.	✓			✓
[36]	2021	Hexad Survey	Categorize programming courses' students into different types/models based on their motivations and preferences in gaming and gamified systems. Accordingly, personalizing the gamification experience for each category.	+ This work is considering the students model approach to personalize the gamification experience. – The Hexad survey is not an effective approach for automatically personalizing gamification. – Relying solely on the motivation metric is insufficient for evaluating the introduced gamification technique.	✓			
[6]	2021	Recommender System	A Polyglot Application	+ An interactive and flexible application that supports both students personalized learning and smart teacher evaluation. + The Personalized learning approach is considering different student learning styles with a range of feedback options, e.g., hints, direct feedback, frequent back and forth interaction, or taking their time and making some mistakes before asking for help. – This work is not considering a clear student modeling approach. – The introduced application is focusing on the student motivation metric only.	✓			
M1: Motivation, M2: Thinking Skills, M3: Cognitive Load, M4: Academic Achievement, MF: Matrix Factorization, SVD: Singular Value Decomposition, NMF: Negative Matrix Factorization								

Table 2. Summary of related works to the topic of AI-driven personalized learning and gamification in programming education (Part 2)

					Evaluation Metrics			
Refs.	**Year**	**Approach**	**Technique/Method**	**Advantages & limitations**	**M1**	**M2**	**M3**	**M4**
[2]	2022	Recommender System and Motivation Survey Questionnaire	A motivated survey questionnaire data was used to design the introduced recommender system.	+ Promising results have been observed in the students' performance and motivation to study programming, while using the introduced recommender system. – Student modeling is not taken into consideration.	✓	✓		
[15]	2024	Collaborative Filtering	MF through SVD and NMF algorithms are used to provide recommendations for lessons and problem-solving solutions.	+ The accuracy of the used recommender system. – The students modeling is not considering in this work. – Thinking skills and cognitive load metrics are not considered in the evaluation of the proposed gamification-based solution.	✓			✓
[8]	2024	Recommender System and AI Planner	PolyGloT Application	+ The use of AI planner enhances the advantages of the introduced recommender system. – The student modeling is not being considered in this work.	✓	✓		
M1: Motivation, M2: Thinking Skills, M3: Cognitive Load, M4: Academic Achievement, MF: Matrix Factorization, SVD: Singular Value Decomposition, NMF: Negative Matrix Factorization								

The introduced Quiz time consists of 4 parts:

(1) A knowledge assessment module designed to test learners' understanding.
(2) A vectorial-based recommendation module, aimed at suggesting personalized collaboration in group playing.
(3) A dynamic advice generator employing fuzzy logic to tailor assistance according to learners' profiles and Misconceptions.
(4) A cognitive learner modeler that supports the previously mentioned modules.

The introduced application was employed within a higher education institution for an academic semester, undergoing evaluation by students and computer science experts using statistical hypothesis testing.

As for the evaluation results, computer science experts confirmed the application's pedagogical adequacy, while students emphasized its positive impact on learning and its practical utility.

Another approach has been used in [36] to personalize gamification in an introductory programming course. The approach consists of conducting Hexad survey to classify a set of students into different categories, in order to adapt the gamification elements to each category.

This survey is based on Hexad model, originally introduced by Marczewski in [29] to classify the users into six types. In this work, the classification is based on a survey of 24 questions to measure user preference for different elements in a gamification environment. By analysing the responses to these questions, the users were classified to the following six hexad user types outlined by Tondello et al. [46]:

(1) Achiever: Driven by the target of competence, this type of user endeavors to prove themselves by finishing tasks.
(2) Disruptor: This user aims to disrupt the system, motivated by a desire to instigate change.
(3) Free Spirit: Driven by a desire for independence, they seek the freedom to express themselves without external constraints.
(4) Player: motivated by external rewards, this user will make extra efforts to obtain these rewards.
(5) Philanthropist: This user is driven by a sense of purpose, where he is willing to give without expecting any reward.
(6) Socialiser: Motivated by the need for social connections, this user aims to build relationships with others.

By considering this Hexad survey-based approach of classifying the students, this work was organized around the following two research questions:

- Do programming students' responses to the Hexad survey provide significant data for classifying Hexad user types?
- How accurate the Hexad classifications in identifying the students' explicit preferences for game elements?

After addressing these research questions, investigating and analysing the data of Hexad survey, the authors have concluded that the Hexad survey is not an effective approach for automatically personalizing gamification.

In [6], an example of gamified software in the field of programming has been presented, where the authors have introduced Polyglot app that consists of four main aspects:

(1) Learning Paths: By using interactive dashboard and notebooks, this application enhances the learning experience that fosters student engagement and teacher effectiveness. In particular, the Polyglot Console helps the teachers to create custom assignments, for each student, using a solution prototype, defining exercise-specific metrics, custom feedback, and scoring criteria. During evaluation, student submissions are compared against the teacher's prototype, ensuring clear alignment with learning objectives.

(2) Learning Exercises: Personalized notebooks with gamification can be used to enhance student engagement in Software Engineering assignments. Using Visual Studio Code's interface, students can interactively complete exercises by submitting their solution in a code cells, receiving automated feedback and scores. The integration with .NET Interactive kernels allows detailed execution insights like variable values and compilation warnings, enabling incremental learning and real-time progress tracking.

(3) Exercises Evaluation and Feedback: The teacher prototype in this application simplifies the evaluation of student submissions using JSON file comparisons between the teacher prototype and the submission. Moreover, this application supports teachers in customizing solution requirements to varying levels of detail, considering different student learning styles with a range of feedback options, including hints, direct feedback, frequent back and forth interaction, or taking their time and making some mistakes before asking for help.

(4) Motivational Elements: Polyglot integrates a Gamification Engine component that allows teachers to define rewards such as points, coins, and medals based on specific conditions like meeting optional requirements.

It tracks student progress, exercise submissions, and updates statuses accordingly, facilitating a personalized learning path. The engine evaluates submissions against teacher-defined criteria, providing tailored feedback to help students understand and correct mistakes, thus promoting continuous improvement and engagement.

A personalized gamified recommender system has been presented in [2]. It consists of providing students with personalized recommendations to address their weaknesses and increase their motivation in programming learning. In addition, a learning motivation questionnaire was used to investigate and assess the students' motivation in learning programming before and after the deployment of the considered recommender system. The results have shown that the personalized gamified recommender system has a significant positive impact on the students' performance and motivation toward learning computer programming.

In [15], a GAmified Mobile Learning Framework (GAMOLEAF) has been introduced. It consists of a learning and assessing mobile application for Java programming language. This application is based on two main approaches, i.e., gamifiation and personalized learning. For the gamification, it includes many elements, such as levels, scores, badges, leaderboard, and feedback. The second approach involves two modules:

(1) A Lessons Recommendation Module (LRecM): provide learners customized lessons based on ratings they have explicitly provided.

(2) A problem-solving Solutions Recommender Module (PSSORecM): This module guides learners to use alternative solutions, based on their behaviours.

Both modules employed collaborative filtering, utilizing Matrix Factorization (MF) through Singular Value Decomposi- tion (SVD) and Negative Matrix Factorization (NMF) algorithms, respectively.

Based on that, an experiment was carried out to assess the learning achievement and motivation of 90 students, when the personalised gamification is deployed to learn java programming language.

Another contribution has been presented in [8], where the authors has introduced a personalized and gamified e-tutoring system for learning modelling and programming skills. This learning system is based on PolyGloT application that organizes learning paths, using different activities, including lessons, coding exercises, and quizzes. These pathways can integrate game narratives to sustain

student motivation.

In light of the aforementioned related works to the topic of AI-driven personalized learning and gamification in programming education, we present in the following sections, the relevant open problems and challenges, as well as future research direction and their potential impacts.

5. OPEN PROBLEMS AND CHALLENGES

In this Section, we identify several open problems and challenges related to the topic of AI-driven personalized learning and gamification in programming education.

5.1. Personalization Accuracy and Adaptability

The different learning methods and preferences of individual students are sometimes hard for current AI systems to recognize and adapt to. For example, a student who thrives with visual aids might struggle with text-heavy materials, while another may excel with interactive simulations. It is necessary to develop AI systems that can dependably infer and modify learning routes in response to real-time feedback and changing student needs. This means an AI should adjust its approach instantly if it detects that a student is having difficulty understanding a concept, perhaps switching from written explanations to video tutorials or interactive exercises.

5.2. Algorithmic Bias and Fairness

AI-driven systems may unintentionally reinforce prejudices in evaluation, feedback, or content recommendation, which could compromise the impartiality and inclusiveness of educational opportunities. For instance, an AI system might favor students from certain educational background or with specific learning styles while providing less support to others. It is necessary to develop algorithms that lessen bias and ensure that all students, regardless of their backgrounds or personal characteristics, have equal opportunity to programming education. This involves refining algorithms to avoid perpetuating existing disparities and incorporating diverse datasets and continuous evaluation processes to promote fairness and equity in educational outcomes.

5.3. Data Privacy and Security

Large-scale learner data collection and analysis for customized recommendations presents serious issues with data privacy, security lapses, and regulatory compliance. Maintaining the efficacy of personalized learning algorithms while implementing strong data privacy techniques and safe storage solutions present a big challenge. This involves not only employing advanced encryption and secure access controls but also ensuring transparent data handling practices and regular audits to safeguard against potential vulnerabilities.

5.4. Scalability and Resource Constraints

Scalability in situations with limited resources is restricted by the significant computing and infrastructure requirements of AI-driven personalized learning. For example, a school or a university with outdated hardware might struggle to run complex AI models that demand high processing power and memory, leading to slower performance or inadequate support. Developing efficient algorithms and lightweight AI models that are compatible with a range of learning platforms—especially those with constrained CPU power—is challenging. This requires designing models that balance performance with resource consumption, such as creating streamlined versions of algorithms that can deliver effective personalization without overwhelming limited computational resources.

5.5. Integration with Pedagogical Practices

Maintaining coherence and consistency with programming educational goals is challenging when integrating gamification and AI-driven individualized learning into current pedagogical frameworks and curricular standards. For example, incorporating AI tools that provide personalized feedback may disrupt traditional teaching methods and complicate lesson planning if they do not align with existing curriculum objectives. It can be hard to provide instructors with the rules and structures they need to successfully use AI technology while ensuring it enhances and supplements more conventional programming teaching techniques. This necessitates the development of clear guidelines and training for educators, alongside tools that seamlessly integrate AI innovations with established pedagogical practices, so that the benefits of personalized learning and gamification complement rather than conflict with traditional instructional approaches.

6. FUTURE DIRECTIONS AND POTENTIAL IMPACTS

Possible suggestions and potential impacts that will be a contributing factor for future researchers are presented in this section.

6.1. An Innovative and Precise student Model for Personalizing the Gamification

As a future research direction, developing an innovative and precise student model for

personalizing the gamification of programming education promises to revolutionize the learning experience. This approach would involve creating dynamic, data-driven models that adapt to individual students' skills, learning styles, and progress. By integrating advanced analytics and AI, this model should tailor educational games to address specific weaknesses and enhance strengths, ensuring that each student receives a customized and engaging learning path. The result would be a more effective and motivating educational environment, where gamification not only makes learning programming more enjoyable but also maximizes each student's potential by providing challenges that are both appropriate and stimulating. This research could pave the way for a more responsive and adaptive educational framework, ultimately fostering a deeper and more personalized mastery of programming skills.

6.2. Advanced AI Techniques

Examining cutting-edge artificial intelligence methods including natural language processing, deep learning, and reinforcement learning to improve the efficiency and flexibility of personalized learning technologies. Enhanced natural language interactions, real-time feedback systems, and adaptive learning pathways in programming education could all have positive effects. For instance, using deep learning algorithms to tailor coding exercises to a student's skill level could significantly boost their comprehension and engagement, while real-time feedback from AI tutors could rapidly address misconceptions and reinforce concepts.

6.3. Mixed Reality and Immersive Learning

In order to create engaging and immersive learning environments, virtual reality (VR), augmented reality (AR), and mixed reality (MR) technologies can be deployed, enhancing spatial thinking skills and collaborative problem-solving in programming education. For example, VR can simulate complex programming environments, allowing students to interact with and manipulate virtual code structures and debugging tools as if they were physically present in a digital workspace. Similarly, AR can overlay code snippets and debugging information onto real-world objects, helping students visualize how their code affects different aspects of a program and providing instant feedback on their programming tasks in an interactive manner.

6.4. Ethical Guidelines and Regulation

Ethical guidelines and regulations for AI-driven Personalized learning and gamification in programming education prioritize student data privacy, fairness in AI algorithms, and transparency in system operations. For instance, ensuring informed consent requires that students and parents are fully aware of how their data will be used and stored, such as through clear consent forms and data protection policies. Additionally, fairness in AI algorithms means that programming learning platforms must be investigated to prevent biases that could affect student evaluations or learning opportunities.

Promoting responsible use of gamification involves creating engaging educational games that do not exploit student data or lead to excessive screen time. Training educators to effectively integrate AI tools is essential, equipping them with knowledge on maintaining ethical standards while utilizing these technologies to enhance the learning experience. These measures aim to foster a supportive educational environment that leverages technology responsibly for optimal student outcomes in programming education.

6.5. Longitudinal Studies and Learning Analytics

To evaluate the long-term effects of AI-driven personalized learning and gamification on student retention, skill development, and career preparedness, longitudinal research and learning analytics should be used. The generation of empirical data to support the development of AI algorithms, teaching techniques, and educational regulations is of high importance.

6.6. Collaborative and Social Learning Platforms

Developing gamification AI-powered collaborative learning environments can significantly enhance programming education by facilitating student interaction, providing mentorship, and promoting the exchange of knowledge. For example, a collaborative platform could enable students to work together on coding projects, receive real-time feedback from mentors, and share insights and resources with their peers. The primary goal is to foster a supportive and engaging learning atmosphere, encourage collaborative problem-solving strategies, and improve access to personalized programming materials and expertise. By creating such environments, we not only enrich the educational experience but also empower students to thrive in a collaborative and resourceful learning community.

7. CONCLUSION

In this literature review, we delve into the integration of AI-driven personalized learning and gamification within programming education.
The corresponding approaches, methodologies, performance evaluation techniques and metrics have been detailed. By synthesizing the related works in the literature, we have identified significant findings that highlight the effectiveness of AI, gamification and personalized tools in enhancing students' motivation and engagements.
Moreover, we have listed and detailed areas requiring further exploration and we have outlined potential future directions for research, as well as unresolved challenges that warrant attention in this evolving field.

Acknowledgments: Research reported in this publication was supported by the Qatar Research Development and Innovation Council [ARG01-0516-230182].

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