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Design Principles of the Gamified E-Assessment for Low Achievers in Introductory Programming

Mahfudzah Othman[1*], Aznoora Osman[2], Siti Zulaiha Ahmad[3], Natrah Abdullah @ Dolah[4]

[1,2,3]*College of Computing, Mathematics and Informatics, Universiti Teknologi MARA Perlis Branch, Arau Campus, Malaysia*
[4]*College of Computing, Mathematics and Informatics, Universiti Teknologi MARA, Shah Alam, Malaysia*

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ABSTRACT

Designing a gamified e-assessment that tailored to the learning requirements of low-achieving students in introductory programming always remains a challenge. By focusing on the integration of gamification and assessment design principles in e-learning platforms for learning programming, this study uses a comparative analysis approach that comprises of three main phases, i) literature search, ii) elicitation and filtration, and iii) review, analysis and extraction of the design principles. Through this qualitative approach, the gamification principles such as the achievement, progression and rules and challenges have been extracted together with the elements of levels, points, badges, progress bars, and leader board. The assessment principles have also been derived consisting of the assessment structure and assessment composition with sub principles of problem-based instructional strategy, formative assessment, post-test strategy, assessment levels, and feedback strategy. The proposed design principles have also been demonstrated through the application in the gamified e-assessment module in an e-learning system.

1. INTRODUCTION

In designing instructional materials for e-learning, it is important to understand the framework of e-learning. Khan (2010) proposes a framework for flexible e-learning that highlights eight dimensions of e-learning, including institutional, management, technological, pedagogical, ethical, resource support, user interface and evaluation. Each dimension has its own focus that contributes to effective learning in an e-learning environment, such as the institutional dimension deals with administrative affairs, academic affairs and others related to student services affairs (Khan, 2010; Haron et al., 2019; Bekele et al., 2022). The management aspect deals with the e-learning system's maintenance and information distribution (Khan, 2010; Angelia et al., 2020). Meanwhile, the ethical dimension refers to social, political, etiquette, and legal issues (Khan, 2010; Haron et al., 2019; Bekele et al., 2022). The technological aspects deal with the infrastructure, hardware and software. Resource support refers to the online support and resources required

[1*] Corresponding author. *E-mail address*: *fudzah@uitm.edu.my*
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for e-learning (Khan, 2010; Haron et al., 2019). In designing instructional materials for any learning environment, the three main aspects that are crucial in enhancing user experiences are the pedagogical, user interface and evaluation dimensions (Khan, 2010; Angelia et al., 2020).

Nevertheless, in learning computer programming through online platforms, many e-learning systems were developed for general population of students, without taking any consideration of low-achieving students, especially in the e-assessment aspects. Low-achieving students tend to be demotivated and loss interests when the learning environment becomes more challenging with difficult assessments to be completed (Mehmood et al., 2020; Kadar et al., 2021). To address this issue, some academicians have utilised the gamification elements to encourage novices for self-evaluation and monitoring to enhance their awareness of their own progression and achievement in this course such as studies by Khaleel et al. (2019) and Alsubhi et al. (2021). They have proposed using gamification elements such as unlocking levels with progress bars, and accumulation of points and badges. Even so, these studies are still lacking in identifying the assessment principles that are suitable for online assessments for low-achieving students. Therefore, this paper focuses on the e-assessment design for introductory programming course that are suitable for low-achieving students based on the gamification and assessment principles derived from the comparative analyses of previous studies. This paper also showcases how the proposed design principles were applied in the e-assessment for introductory programming to cater to the low achievers' learning requirements.

2. LITERATURE REVIEW

2.1 Low Achievers in Introductory Programming

Among novices or beginners in programming, learning introductory programming has always been challenging for many, especially for low-achieving students (Kadar et al., 2021; Othman et al., 2022). Low-achieving students in introductory programming courses can be categorised as students who are slow learners, have low motivation and interest in this subject (Alshammari, 2019; Kadar et al., 2021; Othman et al.,2022). The difficulties that they are facing while learning this subject may also cause them to be less motivated and drop out of this course (Mehmood et al., 2020; Kadar et al., 2021). Other than that, the challenges in trying to grasp the fundamental concepts of introductory programming often cause them to be left behind compared to their high achievers' colleagues (Margulieux et al, 2020; Othman et al.,2022). Despite this, over the years, academicians have strived to overcome this issue by providing the novices with different teaching and learning approaches, especially with the help of educational technologies such as mobile applications, e-learning systems, interactive multimedia, and gamification (Kamunya et al., 2020; Christopher & Waworuntu, 2021). Nonetheless, designing instructional technologies with design principles suitable for the low-achieving students in introductory programming are still lacking, especially in designing the gamified e-assessments, where e-assessments are integrated with gamification and assessment principles. The idea of such integration comes from the fact that to increase students' motivation and gain their interest, the assessment module in the e-learning platform can be gamified with elements that engage students' attention and encourage them to self-monitor their progress (Li et al., 2024). For example, Imran (2023) utilises elements of points, badges, levels and leader board in the gamified e-assessments as the students answer the challenges and progress through each level. His study emphasises on the assessment principles such as post-test strategy and feedback mechanisms that was found useful for the students to stay motivated when test or assessment was given after the learning module with automatic feedback (Imran, 2023). Other than that, Nadja (2022) also integrates gamification principles in the design of the e-assessment where each assessment has different levels of difficulties. Furthermore, the instructional design of the e-assessment for the introductory programming course must also uses problem-based instructional strategy where real-world problems were used to improve students' ability in providing possible solutions (Alshammari, 2019; Nadja, 2022).

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2.2 Gamification Design in E-Learning for Programming

Gamification, defined by Deterding et al. (2011) is "the process of adding game like elements to activities that are not normally game like". Over the years, gamification in the field of instructional technology has gained many interests among academicians. For instance, Christopher and Waworuntu (2021) applied Chao (2015) Octalysis Framework in the development of an online gamified system for teaching Java programming. Chou identified eight core motives namely epic meaning and calling, development and accomplishment, empowerment of creativity and feedback, ownership and possession, social influence and relatedness, scarcity and impatience, unpredictability and curiosity, and loss and avoidance. Christopher and Waworuntu (2021) have incorporated the game elements which include leader board, level, points, and virtual goods in an Android application to teach Java programming. The app was tried on second year students and the students' trial participation revealed and their interest in this subject has increased. Another research done by Khaleel et al. (2019) engaged the MDA framework by Hunicke et al. (2004) to develop a gamified learning website for Java programming. This paper also explained how game mechanics, which are the tools embedded in the programming content proved to improve the students' motivation. Meanwhile, game dynamics, which are the user's interactions with the game mechanics, and the aesthetics of the app, which are the user's emotions during the interaction also played a role in creating a good user interface. The MDA framework was also used to develop an online learning system which incorporated several game elements such as points, badges, levels and leader board.

In designing the gamified e-assessment for introductory programming, it is essential in determining the gamification principles and elements that are suitable to be applied in the context of e-learning environment. Some of the most preferred gamification principles for e-learning systems are rules and challenges, achievement, progression, narrative and sensation (Khaleel et al., 2019; Nadja, 2022). Meanwhile, gamification elements that have been applied in many gamified e-learning systems are points, badges, levels, leader board, Avatar, gifts or virtual goods (Kamunya et al., 2020; Christopher & Waworuntu, 2021). Nevertheless, these studies mainly focussing on gamified e-assessment for general population of students, such as Khaleel et al. (2019) has proved that gamification application in assessment has improved 80% of students' knowledge, motivation and achievement. Meanwhile, in terms of designing the gamified e-assessment that focuses on low achievers in introductory programming, it requires in depth investigation and analysis to determine whether these gamification principles and elements are appropriate for the target users. Further discussions on extracting the gamification design principles for these target users will be discussed in the next section.

2.3 Assessment Design in E-Learning for Programming

Shalatska et al. (2020) emphasize that when designing assessments for an e-learning environment, it is important to consider the assessment structure and composition, which should align with the target audience and the objectives of the assessment. The design should outline the skills to be assessed, offer necessary knowledge and feedback, and provide clear instructions along with explicit assessment criteria, specific characteristics, and settings. The assessment structure pertains to the overall instructional strategies and assessment formats, while the assessment composition focuses on the specific content or tasks involved, including cognitive levels, formats, and feedback strategies (Shalatska et al., 2020; Scherer et al., 2020; Santos, 2023).

In designing the assessment in the e-learning platform especially to learn introductory programming for low achievers, several factors need to be addressed. For instance, the principles for assessment structures must consists of problem-based instructional strategy that emphasises on real-world case scenarios (Scherer et al., 2020; Santos, 2023). Other than that, determining the type of assessment is also important, such as providing the summative or formative assessments. As summative assessments deal with the grading and certification, formative assessments seem to be more appropriate to be implemented in the gamified e-learning environment for learning introductory programming (Pitoyo et al., 2020). Formative

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assessments such as e-quizzes, short-structured questions, multiple choices, sequencing and arranging, true or false questions are more suitable to assess low achievers' knowledge and understanding in introductory programming (Pitoyo et al., 2020). Other than that, for the principles of assessment composition, factors such as post-test strategy, assessment levels and feedback strategies are also essential for the gamified e-assessment. Post-test strategy is needed as low-achieving students need to be assessed after the learning have occurred, to ensure the learning have impacts on their knowledge (Zaharias, 2009). Meanwhile, assessment levels by utilising the Revised Bloom's Taxonomy Cognitive Domain (RBT) are also useful in order to show low-achieving students' progress in solving introductory programming problems, promoting self-regulating mechanism (Santos, 2023). Furthermore, prompt and automated feedback strategies are also useful to improve low achievers' understanding and motivation as they can self-evaluate and monitor their achievements through completed assessments (Lane et al., 2015; Pérez-Clark et al., 2020).

3. METHODOLOGY

A comparative analysis approach by Ahmad and Abdul Mutalib (2015) was adapted in the methodology. This qualitative method includes three main stages, which are i) literature review, ii) elicitation and filtering, and iii) review, analysis, and extraction of design principles.

(i) Literature search

To find articles related to the design principles of a gamified e-assessment in an e-learning platform, an extensive literature search was conducted throughout multiple literature databases, such as Web of Science, Scopus, IEEE Xplore, and Google Scholar. For advanced searches, other keywords have been used, such as "introductory programming AND novices", "introductory programming AND low achievers," "e-learning AND novices," "e-learning AND gamification," "e-learning AND assessment". All related articles identified must also date from 2018 until 2023 and are primarily focusing on the design principles of the gamified e-assessment for introductory programming course.

(ii) Elicitation and filtration

Initially, over 50 articles were chosen based on the previously mentioned keywords. However, to identify the most relevant articles for this research, specific themes were established. These themes required that the selected studies: i) focus on e-learning for introductory programming courses in higher education institutions, ii) involve novices or first-year students in these courses, iii) address the gamification principles and elements applied, and iv) discuss the assessment design used in the studies, in terms of assessment structure and assessment composition that include problem-based instructional strategy, formative assessment, post-test strategy, assessment levels, and feedback strategy. As a result, only ten articles met these criteria and were selected for further review, analysis, and extraction of the design principles. These ten articles thoroughly examined the use of gamified e-assessments in e-learning for introductory programming in higher learning institutions, which significantly influenced the direction of this study.

(iii) Review, analysis and extraction of design principles

Further review and analysis were conducted to ten selected articles by focusing to these pre-determined criteria, i) gamification principles, ii) gamification elements, and iii) assessment principles, with the assessment structure and assessment composition including criteria mentioned above. All the gamification principles and elements, and the assessment principles were then extracted to be applied in the proposed gamified e-assessment for low achievers in introductory programming. Next section will discuss the findings from the review, analysis and extraction of the design principles phase.

4. FINDINGS

https://dx.doi.org/10.24191/jcrinn.v10i1.489

Table 1 depicts all ten selected studies after the thorough elicitation and filtration of the articles.

Table 1. All ten selected studies

No.	Author	Studies
1	Imran (2023)	A Gamified Learning Environment Model
2	Nadja (2022)	A Personalized Gamification Design Model (PeGAM)
3	Poonsawad et al. (2022)	Problem-based Interactive Digital Story Learning Model
4	Alsubhi et al. (2021)	Engagement Framework for E-learning Gamification
5	Kamunya et al. (2020)	An Adaptive Gamification Model of E-learning
6	Winanti et al. (2020)	Gamification Framework for Programming Course in Higher Education
7	Alshammari (2019)	Gamification Design Model for E-learning
8	Khaleel et al. (2019)	Gamification-based Learning Framework for a Programming Course
9	Padirayon (2019)	Gamification Application Architecture and Elements
10	Piteira et al. (2018)	Conceptual Framework of Gamification on Online Courses

Meanwhile, Table 2 shows the findings from the detailed comparative analysis that analyse the gamification principles, gamification elements, and assessment structure and assessment composition from the selected studies.

Table 2. The findings of detailed comparative analysis

No.	Author	Gamification Principles	Gamification Elements	Assessment Structure	Assessment Composition
1	Imran (2023)	Progression, achievement, rules and challenges, narrative	Points, badges, levels, leaderboard, progress bar	Problem-based instructional strategy, formative assessment	Post-test strategy, assessment levels, feedback strategy
2	Nadja (2022)	Progression, achievement, sensation	Badges, leaderboard, progress bar, virtual goods	Problem-based instructional strategy, formative assessment	Post-test strategy, assessment levels, feedback strategy
3	Poonsawad et al. (2022)	Rules and challenges, achievement narrative, sensation	Points, badges, levels, leaderboard, progress bar	Problem-based instructional strategy, formative assessment	Post-test strategy, feedback strategy
4	Alsubhi et al. (2021)	Progression, achievement, rules and challenges	Points, badges, levels, leaderboard, progress bar, timer	Problem-based instructional strategy, formative assessment	Post-test strategy, assessment levels, feedback strategy
5	Kamunya et al. (2020)	Rules and challenges, rewards, achievement, competition, altruism	Badges, leaderboard, progress bar, virtual goods	Formative assessment	Assessment levels, feedback strategy
6	Winanti et al. (2020)	Progression, achievement, rules and challenges	Points, badges, levels, leaderboard	Formative assessment	Post-test strategy, feedback strategy
7	Alshammari (2019)	Rules and challenges, rewards, achievement, progression	Points, badges, levels, leaderboard, timer	Problem-based instructional strategy, formative assessment	Post-test strategy, assessment levels, feedback strategy
8	Khaleel et al. (2019)	Progression, achievement, rules and challenges, altruism,	Points, badges, levels, leaderboard, progress bar	Problem-based instructional strategy, formative assessment	Post-test strategy, assessment levels, feedback strategy

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No.	Author	Gamification Principles	Gamification Elements	Assessment Structure	Assessment Composition
9	Padirayon (2019)	Progression, achievement, rules and challenges,	Points, badges, levels, leaderboard, progress bar	Problem-based instructional strategy, formative assessment	Post-test strategy, assessment levels, feedback strategy
10	Piteira et al. (2018)	Progression, achievement, rules and challenges, narrative,	Points, badges, levels, leaderboard, progress bar	Problem-based instructional strategy, formative assessment	Post-test strategy, assessment levels, feedback strategy

From Table 2, the design principles that are deemed appropriate to be applied in the proposed gamified e-assessment for low achievers in introductory programming are shown in Table 3, Table 4 and Table 5. Table 3 shows the extracted gamification principles that are suitable to be applied, such as principles of achievement, progression, and rules and challenges.

Table 3. Extracted gamification principles

No.	Gamification Principles	Description
1	Achievement	Achievement is represented as completing each level of challenge. Digital badges, points, and leaderboards can represent a students' achievements or accomplishments.
2	Progression	Progression principle demonstrates students' engagement in order to keep them motivated and remain interested. A student's progress can be represented using progress bars and unlocking levels in each e-assessment.
3	Rules and challenges	Rules are represented as defined goal settings, telling users what and how to achieve in each assessment. Assessments can also be seen as challenges or obstacles where students need to overcome by unlocking levels to progress to the next level.

Meanwhile, the gamification elements that are identified based on the gamification principles extracted earlier are points, badges, levels, progress bar and leader board. These elements as listed in Table 4 represent the game mechanics that respond to each achievement, progression, and rules and challenges applied in the e-assessments.

Table 4. Extracted gamification elements

No.	Gamification Elements	Description
1	Points	Points are rewarded when a learner accomplishes a mission, such as completing a challenge or assessment. It can be accumulated based on the rules and challenges designed in the gamified e-assessment.
2	Badges	Badges are rewarded when a learner accomplishes a mission, such as completing a challenge or assessment. It can be accumulated based on the rules and challenges set in the gamified e-assessment.
3	Levels	Levels represent the learner's advancement in the gamified e-assessment. When applied in the assessment, levels can be categorised based on difficulties, from easy to intermediate to hard levels of challenges.
4	Progress bars	The progress bar is a virtual representation of a learner's linear progression as he or she unlocks the challenges or assessments. It helps to engage students with their progress and achievement.
5	Leader board	The leaderboard displays students' achievements and compares accumulated points or badges. It invokes a sense of competition among students.

Lastly, Table 5 shows the extracted assessment principles that will be integrated with the gamification principles and elements for the proposed gamified e-assessment.

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Table 5. Extracted assessment principles

No	Assessment Principles	Sub-principles	Description
1	Assessment Structure	Problem-based instructional strategy	The structure of the e-assessment must include real-world problems to be solved, from easy to hard questions.
		Formative assessment	Using formative e-assessments such as e- quizzes with multiple-choice questions, drag and drop and short-structured questions.
2	Assessment Composition	Post-test strategy	The e-assessments must adequately measure the learning objectives' accomplishment.
		Assessment levels	The e-assessments must include RBT Cognitive Domains to measure the low-achieving students' cognitive performances according to the cognitive levels.
		Feedback strategy	Each e-assessment must provide feedback to the students, which is given at any specific time tailored to the content being studied, the problem being solved, or the task being completed by the learner.

5. THE APPLICATION OF THE PROPOSED DESIGN PRINCIPLES OF GAMIFIED E-ASSESSMENT

This section shows some of the examples of the application of the proposed gamified e-assessment in an e-learning system based on the extracted design principles of gamification and assessment mentioned previously. Fig. 1 demonstrates the application of gamification principles of achievement, progression, and rules and challenges with the elements of levels, progress bars, points, badges and leader board. Figure 1 also depicts the application of the assessment principles of assessment structure and composition with sub principles of problem-based instructional strategy, formative assessment, post-test strategy, assessment levels and feedback strategy in the gamified e-assessment.

For instance, in applying the gamification principles of achievement, progression and rules and challenges, firstly, the assessments were divided into three levels of difficulty based on the RBT Cognitive Domains. The assessment module should be included after the students have completed the learning module, integrating the post-test assessment strategy. Next, each level has its own rules and challenges to be solved that were designed based on the problem-based instructional strategy with real-world problem scenarios. These challenges have variety of formative assessments such as e-quizzes, multiple choice questions, drag and drop, and short structured questions. Each answer will be provided with an automated and prompt feedback from the system, to encourage students' learning acquisition and at the same time improves their knowledge and motivation. When a student has completed a task, the next level will be unlocked, and the system will display the progress of the student's achievement through a progress bar. The progress bar will increase based on each unlock level of assessment. Apart from that, each completed task will contribute to accumulation of points and badges where in the end of each assessment module, the students will be able to see their accumulated points and badges. This will also determine their ranks in the leader board.

https://dx.doi.org/10.24191/jcrinn.v10i1.489

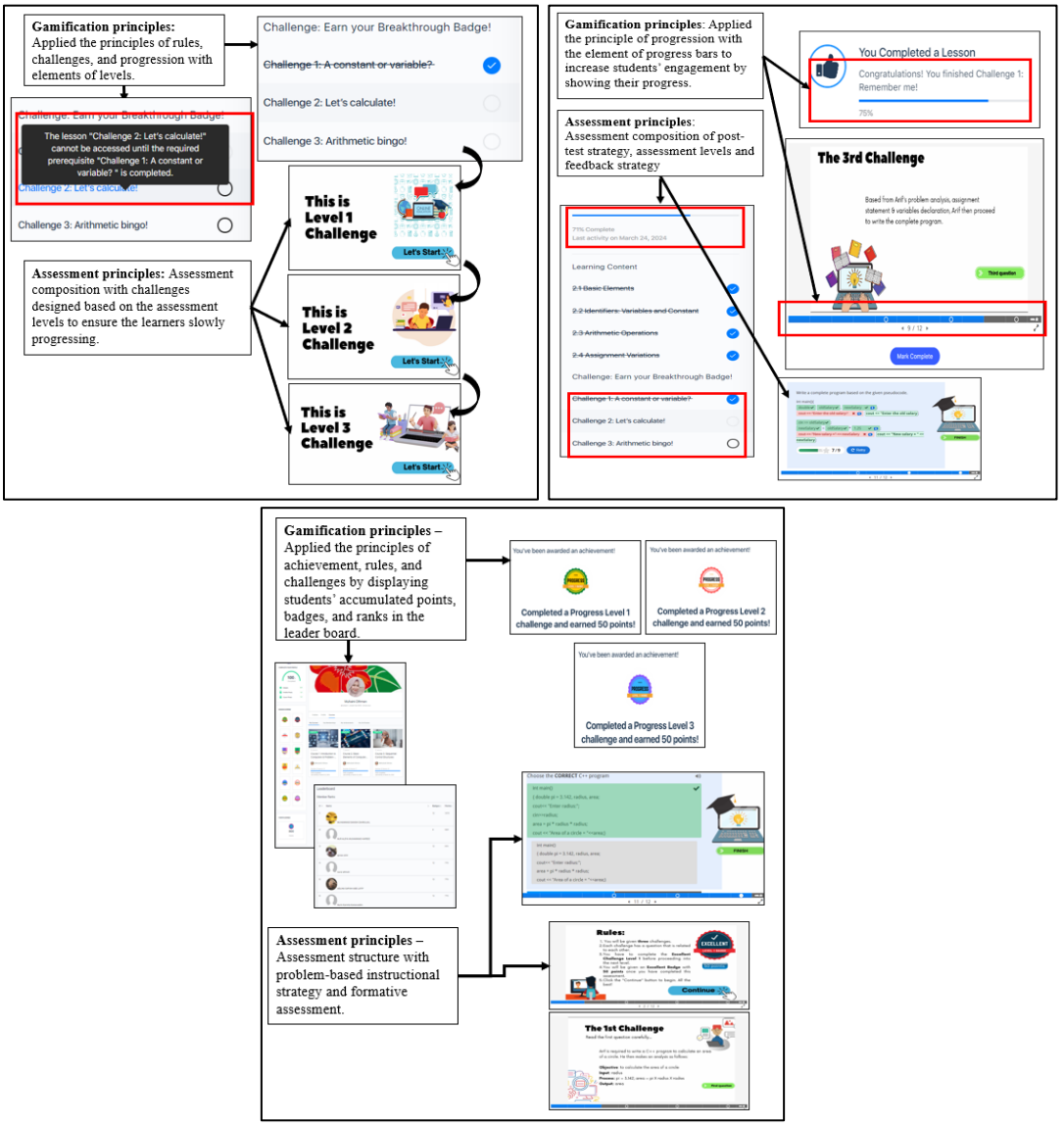

Fig. 1. Samples of application of the extracted gamification principles and elements, and assessment principles in the proposed gamified e-assessment for low achievers in introductory programming

6. CONCLUSION

Designing e-assessments that are suitable for certain group of students in the e-learning systems have always been the interest of many academicians. Nevertheless, designing gamified e-assessments for low achievers in introductory programming possess a challenge for the course instructor. Despite this, through comparative analysis approach comprising of three main phases, the proposed design principles for the gamified e-assessment focusing on the low achievers in introductory programming can be obtained. By investigating and analysing existing studies that suit the theme of the search and filtration, the gamification principles such as principles of achievement, progression , and rules and challenges can be extracted. In

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addition to the selected principles, the gamification elements that suit the principles can also be determined, such as points, badges, levels, progress bars, and leader boards. Other than that, as this study emphasises on the integration of gamification principles and assessment principles, through the extensive work of comparative analysis, the assessment principles have also been derived. Based on the findings, the assessment principles consisting of assessment structure and assessment composition, which then lead to the extraction of the sub principles that include problem-based instructional strategy, formative assessment, post-test strategy, assessment levels and feedback strategy. All these proposed design principles have been successfully applied in the design of the gamified e-assessment in an e-learning system as shown in the previous section. This shows that the proposed design principles with gamification and assessment principles for the e-learning system for low achievers in introductory programming can be effectively implemented. Future research will involve in the development of the prototype of the gamified e-learning system and experimental test with the target users.

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8. CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

9. AUTHORS' CONTRIBUTIONS

Mahfudzah Othman carried out the fieldwork and was the principal author of the whole article. **Dr Aznoora Osman** supervised the fieldwork and prepared the literature reviews. **Ts. Dr. Siti Zulaiha Ahmad** was involved in methodological structures and analysis and findings. Meanwhile, **Assoc. Prof. Dr. Natrah Abdullah @ Dolah** carried out the justifications and conclusion of the research.

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