# INTEGRATING SEGMENTING AND GAMIFICATION PRINCIPLES IN THE DESIGN OF INTERACTIVE GAMIFIED PROGRAMMING ASSESSMENTS FOR LOW ACHIEVERS

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## ABSTRACT

This paper discusses the design of interactive gamified assessments for an introductory programming course based on the multimedia segmenting principle and gamification. The objective is to develop more engaging online programming assessments for low-achieving students. The general design follows Nielsen's design guidelines and incorporates Zaharias' usability evaluation framework with the motivation to learn. The methodology employed the Successive Approximation Model Version 2 (SAM2), comprising two key phases: preparation and iterative design. In the initial phase, a comparative analysis was performed to determine the design principles. The iterative design phase encompassed the application's design via storyboards, the development of the high-fidelity prototype, and users' reviews. A qualitative approach was adopted, involving a user-centred design (UCD) session through focus group discussions with 12 first-year students from the Diploma of Computer Science program, all of whom were low achievers in programming. The participants need to review and rate the prototype based on the scales of the usability recommendations, which are visual design, content design, navigation, interaction, gamification design, and multimedia design. The results from the UCD session revealed that all participants agreed with the usability recommendations integrated into the interactive gamified programming assessments, with the highest mean score of 5.00.

**Keywords:** Interactive, assessment, programming, segmenting principle, gamification.

## INTRODUCTION

Several studies have utilised online learning to facilitate the teaching and learning of introductory programming. For instance, Poonsawad, Srisomphan, and Sanrach (2022) have constructed an interactive digital story learning based on problem-based learning and gamification that focuses on improving students' problem-solving skills. Besides that, Alsubhi, Ashaari, and Wook (2021) have proposed that game elements can be integrated into each level of e-learning activities, such as levels in course learning material, badges, and timers in-course assessment and course assignment, and avatars for discussion segment. Their target was to improve students' engagement in terms of behavioural, emotional, and cognitive factors. Meanwhile, Carbonaro (2018) has utilised a web-based peer code review and assessment to provide feedback to peers and promote students' engagement and participation in the coding experience. The web-based assisted system supports students' programming competence, engagement, and time management capabilities.

Meanwhile, integrating multimedia into online learning for programming has also been widely implemented. For example, Yamani (2021) has developed an adventure game-based multimedia learning that combines gamification elements with multimedia technology. Moreover, Mutiawani, Elfa, Jumadin, Amiren, Fauzie Afidh, and Subianto (2018) have developed a web-based learning with multimedia named Markas C that supplemented the teaching and learning of C programming at Syiah Kuala University in Indonesia. The idea behind integrating multimedia learning into an e-learning portal was to provide an interactive learning environment for students.

However, integrating multimedia learning principles and gamification into the design of interactive online gamified assessments is still in its early stages. As Mayer (2020) suggested, multimedia learning principles aim to reduce unnecessary cognitive load, regulate intrinsic load, and optimise germane load. On the other hand, gamification principles, when properly implemented, can enhance students' motivation and engagement in the learning process (Alabbasi, 2017; Khaleel, Ashaari, Wook & Ismail., 2017). In programming education, students who struggle with this subject are often called low achievers (Turkmen & Caner, 2020; Kadar, Wahab, Othman, Shamsuddin & Mahlan, 2021). These students frequently encounter challenges in understanding fundamental programming concepts, resulting in decreased motivation and interest (Turkmen & Caner, 2020; Kadar et al., 2021). Therefore, educators must find technological solutions that cater to the specific learning needs of these low achievers. Thus, this paper presents the process of designing and developing interactive gamified programming assessments by integrating multimedia learning and gamification principles to support self-regulated learning among low achievers and boost their interest and motivation in this course. Other general design principles for the proposed interactive gamified assessment environment, such as Nielsen's design guidelines for college students aged 18 to 24 years old on the web (Loranger, McCloskey & Nielsen, 2014) and Zaharias's usability evaluation framework with motivation to learn (Zaharias, 2009) were also discussed in this paper.

## BACKGROUND OF STUDY

### Issues with Low-Achieving Students in Introductory Programming

During the initial semester of Computer Science studies, the introductory programming course is compulsory for students (Mehmood, Abid, Farooq & Nawaz, 2020). Furthermore, Mehmood et al. (2020) emphasise the importance of students possessing robust algorithmic and logical thinking skills to excel in computer programming. These cognitive abilities systematically determine students' problem-solving ability using problem-solving strategies and methodologies (Silva, Mendes & Gomes, 2020). Nevertheless, a common challenge many novice-level students may face when studying this subject is their frequent struggle to create programs that address specific problems (Silva et al., 2020). In simpler terms, these students often need help to grasp the fundamental concepts of problem-solving, which demands higher-order computational thinking abilities such as analytical thinking and reasoning (Mehmood et al., 2020). Singh and Narang's (2014) cognitive enhancement hypothesis also claims that underdeveloped logical and reasoning skills can lead to difficulties in other abstract areas of learning, such as mathematical equations, problem-solving, and analytical skills. Due to these difficulties, low-achieving students often feel less motivated as they find the subject complex and challenging. This will eventually cause high failure and dropout rates in many higher learning institutions (Othman, Osman, Abdullah & Ahmad, 2022; Kadar et al., 2021; Mehmood, 2020).

## Gamification in Learning Programming

According to Chao (2015), gamification refers to using game design elements in contexts unrelated to games. In education, gamification is a strategy incorporating game design features to motivate and engage students, significantly improving their curricular, cognitive, and social skills (Alabbasi, 2017; Nadja, 2022). It involves the implementation of tactics that prompt learners to respond, inspire action, and facilitate learning and problem-solving (Alabbasi, 2017; Nadja, 2022). This approach empowers learners, making tasks more appealing and fostering collaboration, effort, and other positive attributes associated with games (ChePa & Yahaya, 2020; Poonsawad et al., 2022).

Moreover, for students with lower academic performance, integrating gamification into educational technology can help enhance their motivation to learn programming. These students, often called slow learners, encounter difficulties grasping the fundamental concepts of programming (Kadar, Mahlan, Shamsuddin, Othman & Wahab, 2022; Multazam, Syahrial & Rusmono, 2023). Their limited ability to logically solve problems leads to difficulty completing assignments and decreases motivation (Kadar et al., 2022; Multazam et al., 2023). Therefore, gamification elements can potentially motivate this group of students and promote their engagement in the learning process. Some gamification principles Chao (2015) suggested to enhance students' understanding and motivation include achievement, progression, feedback, and social influence, among others. Furthermore, gamification elements such as badges, points, levels, and progress bars can be implemented in an online learning environment, as Yamani (2021) proposed.

## Multimedia in Learning Programming

Given humans' limited capacity for real-time information processing, instructional design should strive to create multimedia that reduces unnecessary load, regulates intrinsic load, and optimises germane load. Mayer (2020) proposes twelve principles of multimedia learning to do this, including coherence, signalling, redundancy, spatial contiguity, and temporal contiguity. These principles can be employed to reduce extraneous load. Meanwhile, the segmenting, pre-training, and modality concepts may all be employed to regulate intrinsic load (Mayer, 2020). The multimedia, personalisation, voice, and picture principles are the last four multimedia learning principles utilised to optimise germane load (Mayer, 2020).

These days, numerous academicians in programming education have included Mayer's multimedia learning principles in their design of multimedia learning applications. For instance, Cheah and Leong (2019) investigated the effect of the redundancy principle on C++ programming learning using screencasting, a video recording of the activity on a computer screen activity, usually accompanied by audio narrations. According to their research, students fared better when screen casting and narration were used than when screen casting, narration, and on-screen text were used. Meanwhile, Kumar Kaushal, Kumar, Panda, and Sood (2021) examined the usefulness of signalling, segmenting, and modality principles in teaching data structures using computer animations. Their study demonstrated that using segmentation and modality concepts in animation has increased students' performance in learning programming, particularly data structures.

Based on the background of the study discussed above, this research strives to answer these research questions:

RQ1: What are the suitable gamification and multimedia learning principles to be employed in the design of the programming assessment for low-achieving students?

RQ2: How can the selected gamification and multimedia learning principles be integrated into the design of the programming assessment for low-achieving students?

# METHODOLOGY

We used the Successive Approximation Model Version 2 (SAM2) by Allen (2014) as our methodology to answer the formulated research questions. SAM2 is the extended version of the ADDIE model that incorporates an iterative design process (Allen, 2014). It was selected based on the fact that learning design methods can be adapted to fit iterative approaches, which SAM2 has to offer. SAM2 consists of three main phases: the preparation phase, the iterative design phase, and the iterative development phase. However, only

the first two main phases were discussed in this paper, as the design of the gamified programming assessment will undergo another cycle of reviews before commencing the prototype development. The two main phases and their activities are explained as follows:

## Preparation Phase

During the preparation phase, a comparative analysis was conducted to identify and extract the appropriate gamification and multimedia learning principles to be integrated into the interactive gamified programming assessments. To achieve this, various existing studies that focused on gamified programming e-learning models and interactive video models that incorporate multimedia learning principles were selected. The comparative analysis aimed to extract and integrate gamification and multimedia learning principles into designing interactive gamified programming assessments for low achievers in introductory programming. The selection of these models was based on predefined criteria: a clear and detailed discussion of gamification and multimedia usage in e-learning models and the application of multimedia learning principles in interactive learning applications. Other than that, usability recommendations that serve as the basis for the general design of the interactive gamified programming assessment environment were also explored in this phase, such as Nielsen's design guidelines for college students between the ages 18 and 24 on the web (Loranger et al., 2014) and usability evaluation framework with motivation to learn by Zaharias (2009).

## Iterative Design Phase

In the second phase, three main activities were conducted: application design, prototype development and user reviews. The explanation for each activity is as follows:

### Design the Application

To demonstrate the integration of gamification and multimedia learning principles in designing the interactive gamified programming assessments, a series of storyboards were created using storyboardthat.com based on the selected principles and recommendations identified in the first phase. One crucial factor to consider in designing the storyboards for the interactive gamified programming assessments was to align it with the learning content. As the application aimed to provide interactive and effective online assessments for low achievers in programming, the assessments focused on problem analysis and algorithm development to enhance learners' analytical and problem-solving skills before moving on to coding skills. The interactive gamified programming assessments were segmented into three phases based on problem-solving and algorithm development: problem analysis, pseudocode development, and flowchart development, where each phase consists of a question-and-answer section.

### Prototype Development

Developing a high-fidelity prototype was the next step to showcase the navigation and interactivity of the interactive gamified programming assessments. The gamified assessments' interfaces were designed using the Canva app based on the storyboards developed earlier. They also featured multimedia elements such as text, video, audio, animation, and graphics. The selected gamification principles were also applied in the interactive gamified assessment segments. Subsequently, the application was integrated into LifterLMS, a learning management system developed using WordPress. The interactivity of the gamified assessments was designed and supported through the H5P WordPress plugin.

### Users' Reviews

For data gathering, a focus group discussion was employed, utilising a qualitative approach through a user-centred design (UCD) session, which involved 12 low-achieving students from the first year of the Diploma in Computer Science program. All participants were low-achieving students who enrolled in introductory programming classes and were selected based on their logical-thinking test scores. The instrument used

to measure their logical thinking levels was the Group Assessment Logical Thinking (GALT) Test, which produced a Cronbach's alpha reliability coefficient of 0.722 (Othman et al., 2022). GALT consists of six logical subscales testing such as conservational reasoning, proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, and combinatorial reasoning, which are compiled into 12 test questions (Roadrangka, 1991). Students who scored six marks or less were considered low logical thinking students, thus representing the low achievers for this study. The summary of the participants' demographic info and GALT results is depicted in Table 1.

**Table 1.** Demographic info of the participants for focus group discussion

| | Demographic Info | | |
|---|---|---|---|
| **Age** | Male | Female | Total |
| 18 - 19 | 6 | 6 | 12 |
| **GALT Results** | | | |
| 0 – 1 | 1 | 1 | 2 |
| 2 – 4 | 2 | 3 | 5 |
| 5 - 6 | 3 | 2 | 5 |

During the UCD session, the participants were presented with the interactive gamified programming assessment prototype, and later, they were encouraged to explore and interact with it individually. A questionnaire using a Likert scale of 1 to 5 was also constructed to indicate Strongly Disagree to Strongly Agree, consisting of various design scales, including visual design, content design, navigation, interaction, gamification design, and multimedia design. This instrument was later validated through content validity by three content experts in multimedia, interaction design, and information technology before the UCD session. Each expert must rate 1 for relevant and 2 for not relevant for each item in the instrument. The formula used to calculate the content validity index (CVI) is CVI = n/N, where n is the number of items that are confirmed relevant, and N is the total number of items in the instrument (Rwothumio, Okaka, Kambaza & Kyomukama, 2021). Each expert has recorded a CVI of more than 0.90, which indicates the instrument's validity. The questionnaire was then provided to the participants so they could review and rate the design of the prototype. Finally, the data from the questionnaire were analysed using descriptive analysis via IBM SPSS 26 Statistics.

## RESULTS AND DISCUSSIONS

The results from each phase of the research methodology explained previously will be discussed in this section.

### Preparation Phase: Selection and Integration of the Gamification and Segmenting Principle

#### Comparative Analysis

To identify the appropriate gamification and multimedia learning principles for integration into the gamified online programming assessments, we have chosen ten existing studies of e-learning with gamification and five existing studies that integrate multimedia learning principles into their interactive video learning. As mentioned earlier, these studies were selected based on these predefined criteria: i) a clear and detailed discussion of gamification and multimedia usage in e-learning models and ii) the application of multimedia learning principles in interactive learning applications. Therefore, all these selected studies have explored and modelled the integration of gamification and multimedia learning principles for novices in programming. Table 2 depicts the comparative analysis of the selected e-learning study with gamification and multimedia.

**Table 2.** Comparative analysis of the existing studies of e-learning with gamification

| No | Studies | Gamification Principle | Gamification Elements | Application of Gamification in the Content |
|---|---|---|---|---|
| 1 | Nadja (2022) | Rules and challenges, achievement, empowerment | Levels, badges, rewards | Assessment |
| 2 | Poonsawad et al. (2022) | Achievement, rules and challenges, competition, progression, narrative | Points, levels, badges, storyline, achievements, competition, progression | Assessment |
| 3 | Alsubhi et al. (2021) | Achievement, competition, progression, feedback, levels, ownership | Levels, badges, timer, Avatar, progress bar, leaderboard | Learning & Assessment |
| 4 | Yamani (2021) | Achievement, competition, progression, feedback, social engagement | Points, badges, leaderboard | Assessment |
| 5 | Kamunya et al. (2020) | Achievement, competition, rules and challenges, altruism | Points, badges, levels, leaderboard | Learning & Assessment |
| 6 | Alshammari (2019) | Feedback, achievements, competition | Levels, rewards, badges, points, leaderboard | Learning & Assessment |
| 7 | Shamsuddin et al. (2018) | Feedback, achievement, progression | Points, badges, leaderboard | Assessment |
| 8 | Khaleel et al. (2017) | Achievement, competition, self-expression, altruism | Points, badges, levels, progress bar, leaderboard, Avatars | Learning & Assessment |
| 9 | Piteira et al. (2017) | Feedback, achievement, social engagement, rules and challenges | Points, badges, progress bar, leaderboard | Learning & Assessment |
| 10 | Malas & Hamtini, (2016) | Narrative, progression, achievement | Points, badges, levels | Learning & Assessment |

The comparative analysis presented in Table 2 highlights the prevalent use of gamification principles in previous studies, with achievements, progression, and rules and challenges being the most employed principles in both learning and assessment segments. Meanwhile, progress bars, badges, levels, and points are the frequently used gamification elements. These findings suggest that these game elements are well-suited for implementation in this study's interactive gamified assessment segments. Additionally, it is recommended that these gamification principles be employed in this study to enhance the engagement, motivation, and achievement of low achievers in introductory programming.

Another comparative analysis was conducted to identify suitable multimedia learning principles for integration into the gamified assessments. This analysis selected and examined five studies that utilised interactive videos for learning. The selected studies and multimedia learning principles are presented in Table 3.

**Table 3.** Comparative analysis of the existing studies of interactive video with multimedia learning principles

| No | Studies | Multimedia Learning Principles | Descriptions |
|---|---|---|---|
| 1 | Draus (2020) | Segmenting principle | The study suggests providing segmented videos in chunks of 5 to 10 minutes, which positively impacts students' engagement in learning programming. The research also indicates that low-performing students perform better after watching the instructional videos more frequently. |
| 2 | Kumar Kaushal et al. (2020) | Signalling, Segmenting, and modality principles | The study investigates the usefulness of signalling segmentation and modality principles in teaching data structures using computer animations. The results have shown that animations with segmentation and modality principles have increased students' performance in learning data structures. |
| 3 | Li, Liu, Wang, Zhong & Yu (2019) | Segmenting principle | The study investigates students' debugging process via eye-tracking assessment, where the segmenting principle is applied in tracking eye movement based on specified code errors within the related code blocks. |
| 4 | Cheah & Leong (2019) | Redundancy principle | The study investigates the effectiveness of the redundancy principle in two different modes: video, narration and text, and video and narration only. The latter mode proves to be more effective in learning C++ programming. |
| 5 | Chen & Yen (2019) | Segmenting and modality principles | The study investigates the learner control, segmentation, and modality effects in animated demonstrations. The studies have shown the positive effects of segmentation and learner control on novices with smaller chunks of information. |

The results presented in Table 3 show that the segmenting principle has been frequently utilised in designing interactive videos for leawrning programming, as evidenced by most of the selected studies. As a result, this principle has been chosen to be incorporated into the design of this study's interactive gamified programming assessments. The following justifications have been made for selecting the segmenting principle:

i. When used with the learner control principle, the segmenting principle allows learners to match their learning pace with their individual cognitive needs, enhancing their engagement (Cheah & Leong, 2019; Li et al., 2020).
ii. Studies have shown that the segmenting principle, along with learner-pacing, effectively reduces cognitive load and improves transfer performance (Chen & Yen, 2019; Draus, 2020).
iii. According to research, students learn better from multimedia lessons presented in user-paced segments rather than as a continuous unit, which is achieved through the segmenting principle (Kumar Kaushal et al., 2020; Li et al., 2020).

Therefore, Table 4 shows the gamification design and multimedia design's usability recommendations, as extracted based on the selected gamification principles and the segmenting principle.

**Table 4.** Usability recommendations are based on the selected gamification principles and the segmenting principle.

| Gamification and Multimedia | Usability Recommendations |
|---|---|
| Gamification Design | 1. Utilize rules and challenges to enhance learners' cognitive skills (application of rules and challenges principle). |
| | 2. Display learners' progress in completing challenges with a progress bar (application of progression principle). |
| | 3. Award badges for each achievement, such as a Progress Badge for completing each level of challenge (application of achievement principle). |
| | 4. Assign points for completing a challenge (application of achievement principle). |
| Multimedia Design | 1. Learning is more effective when multimedia content is segmented into smaller, easily digestible segments (application of multimedia segmenting principle). |
| | 2. User-controlled presentation of multimedia content leads to better absorption of information (application of multimedia segmenting principle). |

As mentioned previously, apart from the gamification and multimedia design usability recommendations in Table 4, to make the interactive gamified programming assessments more effective and motivating to the target users, the general design of the prototype is also being guided by Nielsen's design guidelines for college students on the web age 18 to 24 years old (Loranger et al., 2014) and usability evaluation framework with motivation to learn (Zaharias, 2009). Nielsen's design guidelines were chosen because of their effectiveness in guiding the design of interactivity and navigation between the application and the target users. Meanwhile, usability recommendations from Zaharias (2009) were deemed suitable for triggering motivation among low achievers. Therefore, Table 5 shows the selected usability recommendations that become the prototype's general design, consisting of visual design, content design, navigation, and interaction.

**Table 5.** General design's usability recommendations

| General Design | Usability Recommendations based on Nielsen's Design Guidelines and Zaharias Usability Evaluation Framework with Motivation to Learn |
|---|---|
| Visual Design | 1. Attract with clean, simplistic design |
| | 2. Feature visual design that matches the learning content |
| | 3. Use colours sparingly |
| Content Design | 1. Choose words and concepts that are related to the learners (Computer Science students) |
| | 2. Learning contents are divided into small, clear groupings. |
| | 3. Minimize redundancy (using text, images, video, animation, and narration is appropriate). |
| | 4. Has a question-and-answer format related to the learning contents. |
| Navigation | 1. Use familiar navigation schemes. |
| | 2. Learners can choose (easily) what parts of the course to access, the order and pace of studying. |
| Interaction | 1. Use media appropriately to assist in highlighting and learning critical concepts. |
| | 2. The course provides meaningful interactions (for example, embedded quizzes) when there are long sections of text or video. |
| | 3. The course uses game elements or simulations, role-playing activities, and case studies to gain attention and maintain learners' motivation. |
| | 4. The course engages learners in tasks closely aligned with the learning goals and objectives. |

Upon completion of the preparation phase, the first research question was answered, and we successfully determined the suitable gamification and multimedia learning principles to be integrated into the design of the programming assessment for low-achieving students.

## Iterative Design Phase: Design of the Storyboard

After selecting the gamification and segmenting principles and the other general design guidelines, the design process of the interactive gamified programming assessments' storyboard followed. The content of the interactive gamified assessments was segmented, focusing on problem-analysis and design activities, as stated in the methodology section. Several crucial factors were considered in integrating the multimedia segmenting principle into the interactive gamified programming assessments' design. These include the assessment's segmentation, gamification elements to be integrated, and user pace control and interactivity features.

### Segmentation of the Interactive Gamified Assessment

To enhance the learning experience of introductory programming, problem analysis and design are divided into different phases, including problem analysis, problem design using pseudocode, and problem design with flowcharts. Thus, each phase will have its corresponding assessment segment in the interactive gamified assessments. Furthermore, a question-and-answer section with an interactive quiz will be incorporated into each phase to make the assessment segments more engaging. These segments will also feature multimedia elements like text, graphics, audio (narration), and animation.

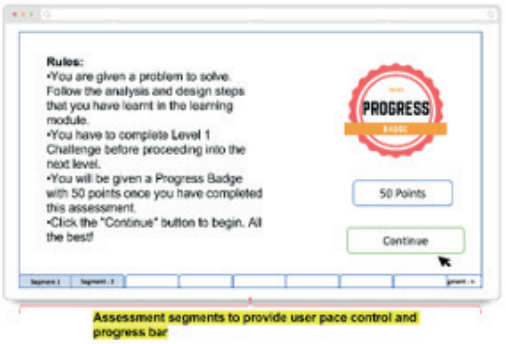
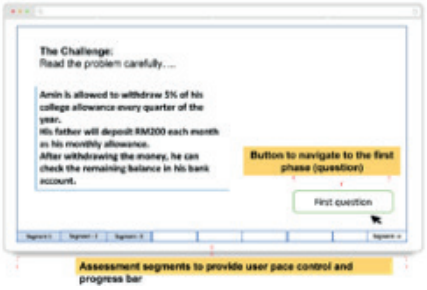
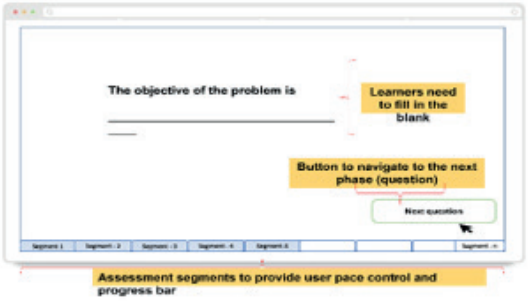
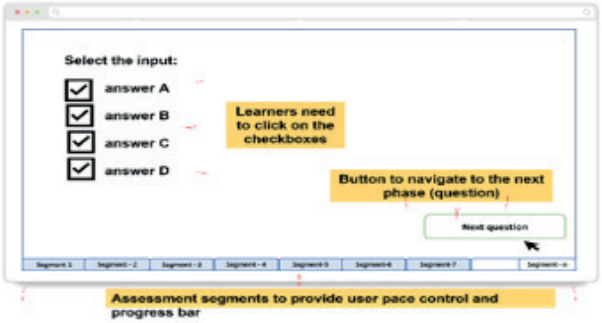
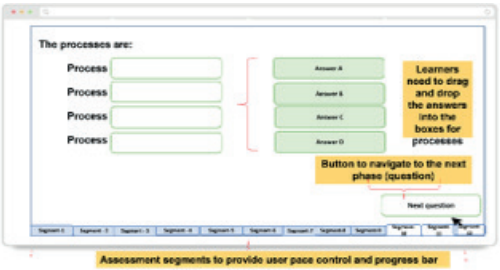
### Integrating Gamification Elements into the Assessment

To incorporate gamification elements into the design of the interactive assessment, challenge questions were categorised into three difficulty levels: Easy, Moderate, and Hard. Each challenge level had rules for learners to follow, including earning points and badges upon completion. Advancement to the next level of challenges depended on completing the previous level. No timer was included to alleviate pressure, as the primary goal was to motivate low-performing students to finish the assessment. A progress bar was added to display the percentage of the learner's progress, serving as a tool for motivation and engagement.

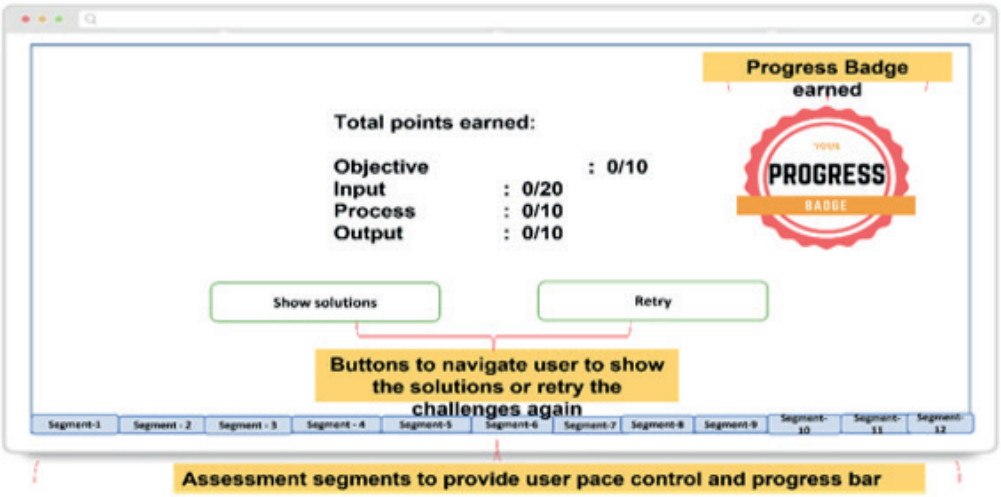
### Integrating User Pace Control and Interactivity Features

The segmenting multimedia learning theory endorses the notion of learners learning at their own pace, particularly for those who struggle academically. Thus, no timer was added to regulate the duration for learners to complete each assessment level by the user pace control theory and the segmenting principle. The interactive assessments featured graphics and animations to aid learners in navigating through the phases of each challenge and completing the embedded interactive quizzes. Table 4 presents a sample of each interactive gamified assessment storyboard with gamification elements and segmentation.

**Table 4.** Sample of the storyboard for the interactive gamified programming assessment with gamification and segmenting principles

| **Sample of storyboard for the interactive assessment segments with gamification and segmenting principles – Challenge Level 2 (Moderate)** | |
|---|---|
|  <br>**Segment:** Introduction<br>**Multimedia elements:** Text, graphics, animation, audio and video<br>**Gamification elements:** Progress bar |  <br>**Segment:** Rules<br>**Multimedia elements:** Text, graphics, animation, audio and video<br>**Gamification elements:** Badge, points, progress bar |
|  <br>**Segment:** Challenge Question<br>**Multimedia elements:** Text, graphics, animation, audio and video<br>**Gamification elements:** Badge, points, progress bar |  <br>**Segment:** Interactive question-and-answer (fill in the blank)<br>**Multimedia elements:** Text, graphics, animation, audio and video<br>**Gamification elements:** Badge, points, progress bar |
|  <br>**Segment:** Interactive question-and-answer (checkboxes)<br>**Multimedia elements:** Text, graphics, animation, audio and video<br>**Gamification elements:** Badge, points, progress bar |  <br>**Segment:** Interactive question-and-answer (drag and drop)<br>**Multimedia elements:** Text, graphics, animation, audio and video<br>**Gamification elements:** Badge, points, progress bar |

**Sample of storyboard for the interactive assessment segments with gamification and segmenting principles – Challenge Level 2 (Moderate)**




**Segment:** Total score
**Multimedia elements:** Text, animation
**Gamification elements**: Badge, points, progress bar

## Iterative Design Phase: Development of the High-fidelity Prototype

The high-fidelity prototype was developed since the participants must experience how interactivity and navigation are executed in a natural learning environment. Figure 1 shows the interactive gamified programming assessment interfaces constructed based on the previously developed storyboard, where all the usability recommendations were employed. In the interactive gamified programming assessment segments, the gamification principles applied are the rules and challenges represented by the questions asked, the progression principle represented by the progress bar, and the achievement principle presented via the points scored and badges earned. Meanwhile, the multimedia learning principle applied is the segmenting principle

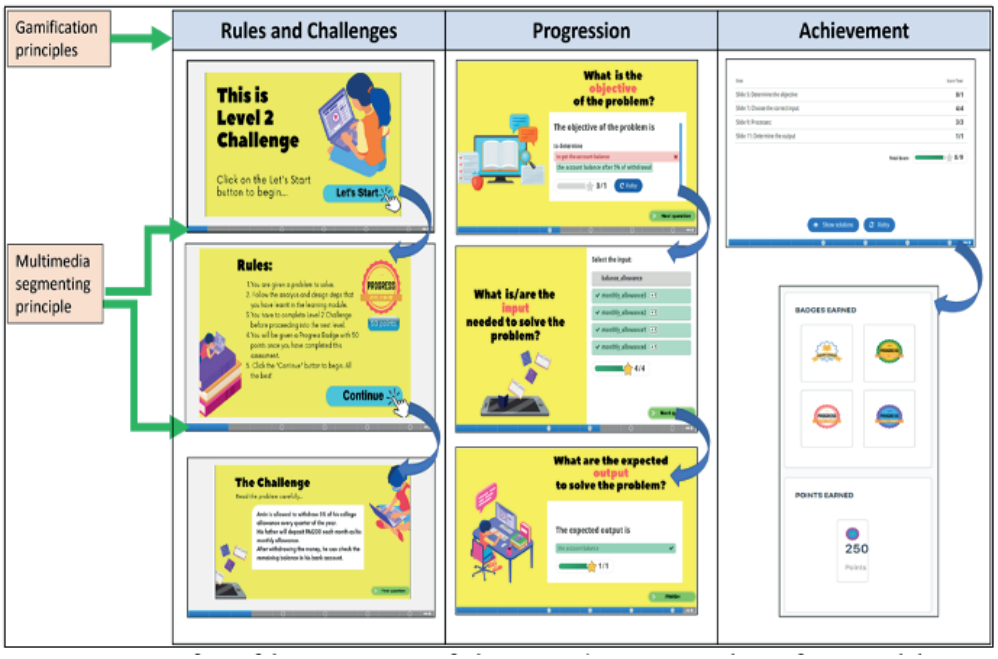



**Figure 1.** Interfaces of the interactive gamified assessment's prototype with gamification and the segmenting principle

## Iterative Design Phase: Users' Reviews

As mentioned earlier, the participants in the UCD session were asked to review and rate the design of the interactive gamified assessment based on the scales of visual design, content design, navigation, interaction, gamification design and multimedia design. The results of the descriptive analysis derived from the UCD session are depicted in Table 5.

**Table 5.** Results of UCD session

| **Visual Design** | **Mean** | **Std. Dev.** |
|---|---|---|
| Attract with a clean, simplistic design | 4.50 | .522 |
| Feature visual design that matches the learning content | 4.83 | .389 |
| Use colours sparingly | 4.75 | .452 |
| **Content Design** | | |
| Choose words and concepts that are related to the learners (Computer Science students) | 4.75 | .452 |
| Learning contents are divided into small, clear groupings. | 4.67 | .492 |
| Minimize redundancy (using text, images, video, animation, and narration is appropriate). | 4.83 | .389 |
| Has a question-and-answer format related to the learning contents. | 4.83 | .389 |
| **Navigation** | | |
| Use familiar navigation schemes. | 4.67 | .492 |
| Learners can choose (easily) what parts of the course to access and the order and pace of studying. | 4.75 | .452 |
| **Interaction** | | |
| Use media appropriately to assist in highlighting and learning critical concepts. | 4.83 | .389 |
| The course provides meaningful interactions (for example, embedded quizzes) when there are long sections of text or video | 4.92 | .289 |
| The course uses game elements or simulations, role-playing activities, and case studies to gain attention and motivate learners. | 4.92 | .289 |
| The course engages learners in tasks closely aligned with the learning goals and objectives. | 4.92 | .289 |
| **Gamification Design** | | |
| Utilize rules and challenges to enhance learners' cognitive skills (application of rules and challenges principle). | 5.00 | .000 |
| Display learners' progress in completing challenges with a progress bar (application of the progression principle). | 4.92 | .289 |
| Award badges for each achievement, such as a Progress Badge for completing each level of challenge (application of achievement principle). | 5.00 | .000 |
| Assign points for completing a challenge (application of achievement principle). | 4.75 | .452 |
| **Multimedia Design** | | |
| Learning is more effective when multimedia content is segmented into smaller, easily digestible segments (application of multimedia segmenting principle). | 4.75 | .452 |
| User-controlled presentation of multimedia content leads to better absorption of information (application of multimedia segmenting principle). | 4.83 | .389 |

Based on the results of the UCD session in Table 5, the participants agreed on the usability recommendations in the prototype design, with mean scores between 4.50 and 5.00. The gamification design scale shows the

highest result, with a 5.00 mean score for applying the rules and challenges principle and achievement principle. Meanwhile, the multimedia design scores between 4.75 and 4.83 for applying the segmenting principle with user-paced control. Other general principles recommended in the prototype also scored high mean scores, such as 4.83 for visual design that matches learning content and content design that minimises redundancy and provides a question-and-answer format related to the learning content. Furthermore, the participants also agreed to the navigation recommendation where learners can easily choose what parts of the course to access, the order and pace of studying with a 4.75 mean score, and all usability recommendations for the interaction scale have scored high mean scores from 4.83 to 4.92. These results show that integrating gamification and segmenting principles and the proposed general principles into designing interactive gamified assessments for introductory programming courses has been proven effective for low-achieving students. Further discussions with the participants have also been conducted to collect more insightful comments and recommendations for improving the gamified programming assessment. Table 6 summarises the comments recorded from the session.

**Table 6.** Other comments and recommendations

| No | Other comments or recommendations |
|---|---|
| 1 | The proposed design manages to provide components and elements that are suitable for low achievers and can be applied in the actual prototype. |
| 2 | The game elements chosen are appropriate to boost students' motivation and engagement. |
| 3 | Challenges designed for the assessment based on gamification elements (levels, points, and badges) are suitable for low-achieving students. |
| 4 | The combination of the multimedia elements is suitable for the low achieving students. However, voice narration can also be included in the assessment design. |
| 5 | The gamification principles are suitable; I recommend adding a leaderboard to the game elements. |
| 6 | Minimise redundancy, especially for the combination of narration and background audio. |
| 7 | Combining images and narration can be optional (learners can turn on/off audio). |
| 8 | The assessment levels or challenges are suitable to be applied. However, we need to consider displaying the cognitive level in the assessment section of the prototype. |
| 9 | Overall, it is an excellent design to be applied in a learning management system where the consideration is towards low-achieving students who might face challenges in understanding and staying engaged in their learning of programming fundamentals. |

The second research question was answered and achieved upon completing the iterative design phase, which consisted of sub-phases of designing the storyboard, high-fidelity prototype development, and user reviews session. All the selected gamification and segmenting multimedia learning principles have been successfully integrated into the design of the gamified programming assessment and received positive reactions from the target users, who are low achievers in introductory programming.

## CONCLUSION AND FUTURE RESEARCH

Developing interactive gamified programming assessments customised for introductory programming students with lower academic performance involved a comprehensive series of stages. These stages leveraged gamification principles, such as achievement, progression, and rules and challenges, in conjunction with the segmenting principle, to effectively enhance the learning process for this specific student group. For instance, the incorporation of the rules and challenges principle was manifested in the design through the presentation of narrative-based questions that outlined explicit rules to be adhered to, accompanied by a series of challenges to be surmounted. Likewise, the prototype integrated the progression principle by featuring a user-friendly progress bar, enabling learners to monitor their advancement effortlessly.

Furthermore, applying the achievement principle was instrumental in allowing students to earn badges and accumulate points, representing their overall performance and accomplishments. Additionally, including the segmenting principle within the prototype played a crucial role in promoting self-regulated learning among students. This was achieved by dividing the assessment into smaller, manageable segments and offering user-paced control features, granting individuals the flexibility to complete the assessment at their preferred pace. The general design guidelines incorporated in the design based on Nielsen's design guidelines and Zaharia's usability evaluation framework with motivation to learn also have helped the prototype be more effective, engaging, and motivating. Future research will explore additional gamification principles such as social influence, where research about friending or group quests can be explored in a computer-collaborative learning platform, or the principle of ownership, where students may exchange points or badges to progress into the next level of challenges. Meanwhile, another multimedia learning principle that can also be considered is the signalling principle, which highlights the importance of programming terms or pre-training that helps students become familiar with basic programming concepts before proceeding into advanced programming.

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