Impact of Student's Programming Experience on Cognitive Skills: Towards a Gamified Multimedia Learning Approach

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Abstract: This study investigated the impact of students' programming experience on their cognitive skills, thus proposing a gamified multimedia learning model to provide a meaningful programming experience to novice programmers. To achieve this, ninety-seven students from the first semester of the Diploma in Computer Science, Universiti Teknologi MARA Perlis Branch, Malaysia, have taken part in the Group Assessment Logical Thinking Test (GALT). The objective is to investigate the number of high logical thinkers (HLT) and low logical thinkers (LLT) and whether their programming experience correlates with their cognitive skills or not. Further analysis was conducted to predict whether exposure to programming experience, in the long run, will positively influence their cognitive skills. Descriptive analysis has shown that the number of LLT is higher than HLT at 54.6%, and Spearman Rho's correlation analysis has shown a moderate positive correlation between programming experience and logical thinking skill at 0.654, a significant value of $p < 0.05$. Linear regression analysis also has shown that exposure to programming experience will positively affect students' logical thinking skills at 0.172, a significant value of $p < 0.05$. From the study, a gamified multimedia learning model for novice programmers is proposed, with integration between problem-oriented instructional strategies, segmenting principle of multimedia learning, and gamification with assessment and rules or goals as game attributes that involve points or badges, and levels of progress bars as the game elements.

Keywords: Programming experience, Cognitive skills, Gamification, Multimedia learning, Instructional design

1. Introduction

In Malaysia's digital education landscape, Computer Science subject has been introduced in secondary schools all over Malaysia under the revised Secondary School Curriculum (Kurikulum Standard Sekolah Menengah, KSSM) 2017, where the subject is the replacement of the ICT subject and is being taught to students from Form 1 up until Form 3 (Ministry of Education, 2015). This subject is divided into three modules: computer programming, database management, and human-computer interaction, emphasizing problem-solving and computational thinking abilities (Zaharin et al., 2018). Introducing these modules aims to pique students' interest in Science, Technology, and Engineering

(STEM) education and establish a feeder system for higher academic institutions in the fields of Science, Mathematics, and Computing.

Meanwhile, at the tertiary level, Computer Science courses are offered at most of Malaysia's public and private universities. For example, at Universiti Teknologi MARA (UiTM), programs in computing studies include a Diploma in Computer Science, a Bachelor of Computer Science, and other degrees offered by the Faculty of Computer and Mathematical Sciences. According to the Malaysian Ministry of Education's (MOE) 2018 and 2019 statistics on student intake, enrolment, and graduation in public universities in the fields of Science, Mathematics, and Computing, the number of intakes in 2019 was slightly lower than in 2018, even though the number of graduates produced was higher than in 2018 (Ministry of Education, 2019). In 2018 and 2019, the overall proportion of graduates produced was 22% of total enrolments in these two years. The percentage of graduates in the fields of Science, Mathematics, and Computing is controversial since it reflects either high dropout rates or the fact that most of them did not graduate on time.

Nonetheless, high dropout rates among students studying Computer Science have been a global concern (Mehmood et al., 2020). According to the 2020 UK Debut Career report, Computing Science studies had the highest dropout rate, which was 9.8 percent in the academic year of 2017/2018 (Frobisher, 2020). Additionally, previous researchers have noted that the high rate of attrition occurred for a variety of reasons. One explanation is that the subject of programming is thought to be difficult, which will affect students' interest and willingness to learn it (Mehmood et al., 2020). As a result, it is necessary to reconsider how the subject should be taught.

Meanwhile, in Malaysia, under Shift 9 of the Malaysian Education Blueprint 2015-2025 for Higher Education, the government has emphasised the importance of incorporating blended-learning models that combine face-to-face classroom instruction with computer-mediated learning, thereby globalising online higher education (Ministry of Education, 2015). The waves of Industrial Revolution 4.0 (IR 4.0) have also had a favourable effect on the education sector, resulting in Education 4.0. The incorporation of various technologies, such as robotics, augmented reality (AR), and the internet of things (IoT), among others, has altered the landscape of the traditional classroom, transforming it into a more blended-learning environment (Zaharin et al., 2018). Thus, by embracing Education 4.0, MOE should prioritise integrating educational technology into the teaching and learning process as the most recent way of digitalising higher education, with the goal of sustaining Malaysian students in a competitive labour industry as a result of IR 4.0. (Zaharin et al., 2018).

To support the Malaysian government's objective for globalised online learning in higher education and to reduce student attrition, computer programming teaching and learning must also incorporate technology to enhance students' interaction and interest in the topic. Over the years, scholars have examined and presented methods that many academics worldwide have already applied to improve students' learning experiences and skills in algorithm development and programming, including digitalizing teaching and learning using educational technologies. E-learning systems, multimedia courseware, educational games, and mobile learning are just a few of the educational technologies designed to aid in the teaching and learning of computer programming (Silva et al., 2020).

Nonetheless, all the educational approaches discussed above are primarily focused on increasing students' understanding of programming topics and passing the course, while research on enhancing students' cognitive abilities or logical thinking skills is still in its infancy. Additionally, these educational tools are heavily reliant on certain technology, like multimedia, mobile, and interactive games. There has been little discussion about hybridising these technologies in order to increase students' programming experiences and cognitive skills. Therefore, this paper discusses the effects of students' programming experience on their cognitive skills by first investigating the logical thinking levels among the first-year Computer Science students, then examining the correlation between their programming experience and cognitive skills. After that, further investigation was conducted to investigate whether exposure to programming experience has a long-term effect on students' cognitive skills. Finally, this article offered a hybrid gamified multimedia learning model to enhance students' programming experiences, thus, impacting their logical thinking skills. This paper is organized as follows; where Section 2 is the discussion on the background of the studies, Section 3 explains the materials and methods adopted for this study, and Section 4 discusses the results and analysis. Finally, Section 5 is the conclusion derived from this study.

2. Background of Studies

2.1 Cognitive Skills and Educational Technologies in Learning Programming

According to Bostro and Sandberg (2009), cognition is the process by which humans organize information. It consists of perception, memory, attention, comprehension, coordination, and reasoning. Thus, cognitive talents can be described as the capacity for performing simple to more complicated cognitive tasks that need mental processing (Bostro & Sandberg, 2009). Additionally, Bostro and Sandberg (2009) state that human cognitive abilities can be classified as memory, attention, language, visual and spatial processing, interpersonal and intrapersonal skills, as well as logical and reasoning abilities.

Meanwhile, in the first semester of Computer Science studies, the introductory programming course is one of the mandatory subjects that the students must take (Mehmood et al., 2020). Additionally, Mehmood et al. (2020) assert that students must have strong algorithmic and logical thinking skills in order to become proficient in computer programming. These cognitive abilities will eventually reflect students' capacity to solve problems deductively via problem-solving strategies and approaches (Silva et al., 2020).

Despite this, one of the most typical difficulties encountered while learning this subject is that the majority of students at the novice level frequently struggle to construct programs in order to solve specified problems (Silva et al., 2020). In other words, these students frequently struggle to grasp the core principles of problem-solving, a cognitive ability that requires higher-order thinking abilities such as analytical reasoning and logical reasoning (Mehmood et al., 2020). This circumstance clearly correlates with Singh and Narang's (2014) cognitive enhancement hypothesis, which states that underdeveloped logical and reasoning abilities would result in difficulties with mathematical equations, problem-solving, analytical skills, and other abstract learning.

As a result, the Computer Science community, throughout the years, has been working on designing more inclusive learning environments with effective instructional approaches that provide meaningful experience and have positive influences on students' cognitive skills (Mehmood et al., 2020). For instance, Halim and Phon (2020) have demonstrated that a mobile learning application had a significant impact on students' motivations and interests, whereas Sabjan et al. (2021) demonstrated that well-designed web-based learning platforms or MOOCs provided learners with superior learning experiences. Despite this, a lack of research has been conducted on gamified multimedia learning, which hybridizes gamification and multimedia learning and its effects on students' cognitive skills. Therefore, this study examined the impacts of students' experience in programming on their cognitive skills and proposed a model of gamified multimedia learning for novice programmers in order to create a more engaging and meaningful learning experience.

2.2 Theoretical Framework

According to cognitive learning theory, both internal and external influences can influence an individual's mental processes in order to supplement learning (Seyyed & Leah, 2021). This demonstrates that the learning environment does influence the development of lifelong learning skills, confidence, abstract thinking, and problem-solving abilities (Mayer & Moreno, 2003). Additionally, cognitivism theory emphasizes the importance of goal-directed, active learning and constructive processes in the learning process (Seyyed & Leah, 2021). As a result, cognitive learning strategies must incorporate processes such as planning and goal setting, as well as the selection of stimuli and experimentation that require learners to manage their acquired knowledge (Seyyed & Leah, 2021). According to this idea, the way a learner organizes and stores new information in his or her memory and then connects it to their prior knowledge via cognitive structures has a substantial impact on the individual learning outcome (Mayer, 2020). However, for instructional software to be truly helpful in reducing a learner's cognitive load, appropriate guidance must be offered. Thus, in order to provide a gamified multimedia learning environment, instructional design should emphasize the development of the structure, process, and method of instruction, as well as their impact on learning performance.

Tennyson and Rasch (1988) established an instructional design methodology that linked cognitive learning theory with instructional prescriptions. This model incorporates components of the working memory system and time allocation for learning based on learning objectives and instructional techniques, with 70% of learners' instructional time focused on applying and enhancing knowledge. Tennyson and Rasch (1988) have recommended a variety of instructional strategies for computer-based instruction, including expository, practice, problem-oriented, and complex problem strategies, as well as self-directed experiences.

Along with serving as a model for gamified multimedia learning, the cognitive theory of multimedia learning (CTML) is critical. Mayer and Moreno (2003) define multimedia learning as "learning through images and words," whereas multimedia instructions are "presentations of images, either static or dynamic, and words, either printed or spoken, that are utilised to facilitate learning." Additionally, Mayer (2020) defines meaningful learning as the ability of the learner to have a thorough grasp of the provided information and to be able to extract the most salient components, organise them into a coherent cognitive framework, and integrate them with prior knowledge.

Mayer's CTML was developed based on three assumptions: the dual-channel assumption, which states that humans have separate systems for processing verbal and pictorial materials, and the limited-capacity assumption, which states that humans have a limited capacity to process information from these different channels concurrently, and the active-processing assumption, which stated that meaningful learning involves cognitive processing that integrates pictorial and verbal representations (Mayer & Moreno, 2003). This idea is mainly based on cognitive load theory, which states that information acquired throughout the learning process will result in one of three unique forms of processing: extraneous, intrinsic, or germane load (Mayer & Moreno, 2003). Given humans' limited capacity for real-time information processing, instructional design should strive to create multimedia that minimizes extraneous load, regulates intrinsic load, and optimizes germane load. Mayer (2020) proposes twelve multimedia design principles, including coherence, signalling, redundancy, geographical contiguity, and temporal contiguity that can be employed to reduce extraneous load. Meanwhile, the segmenting, pre-training, and modality concepts can be employed to manage intrinsic load, and the multimedia, personalization, voice, and image principles are the last four multimedia design principles utilized to optimize germane load (Mayer, 2020).

For this study, the segmenting principle was applied to a gamified multimedia learning model in which learners have control over the learning process and can progress at their own pace. Meanwhile, learning contents should be appropriately chunked to allow learners to process the information adequately. This idea is consistent with Tennyson and Rasch's (1988) instructional design model, which recommended allocating learning time according to learning objectives to ensure that learners had adequate time to apply and improve their knowledge. Furthermore, in the theoretical framework, the construction of the gamified multimedia learning model requires an understanding of gamified learning theory. Landers (2015) developed the gamified learning theory, in which he suggested that gamification through the use of game features has an effect on learning-related behaviour or attitude, which in turn affects the quality of instructional design and learning outcomes. According to Bedwell et al. (2012), there are nine distinct types of game attributes. These include action language, assessment, conflict or challenge, control, environment, game fiction, human interaction, immersion, and rules or goals. Nevertheless, because gamification is defined as applying game elements to non-game contexts, it is appropriate to target and adapt only specific game attributes to the gamified learning environment (Landers, 2015). Thus, this study focuses on applying game elements in the assessment and rules or goals categories, specifically using points or badges, levels, and progress bars in the learning materials, which also incorporates the multimedia learning segmenting principle.

3. Materials and Methods

This research has been conducted quantitatively using the descriptive and correlational research methods, which comprises three main phases; i) investigating the correlation between students' programming experience and cognitive skills, ii) investigating whether exposure to programming experience will impact students' cognitive skills in the long run and iii) proposing the gamified multimedia learning model for introductory programming.

The target population for this research is the first-year students from the Diploma in Computer Science program, Universiti Teknologi MARA (UiTM) Perlis Branch, Malaysia. The non-probability sampling technique known as convenient sampling has been chosen because the participants are readily and easily available, making it more convenient and inexpensive. Based on this sampling technique, ninety-seven male and female students enrolled in the first semester of the Diploma in Computer Science, UiTM Perlis Branch, Malaysia, were selected to be part of the experimental testing.

Descriptive statistics, correlation, and regression analysis were conducted throughout this study. The results were then analysed via IBM SPSS Statistics 26 and presented in tabular forms. The research methods are further discussed and elaborated on in the next section.

3.1 Investigating the correlation between students' programming experience and cognitive skills

For the first phase, the selected students were asked to participate in a Group Assessment Logical Thinking (GALT) Test, an instrument commonly used to measure students' logical thinking skills. This instrument, which has been widely used in education, consists of six logical subscales testing such as conservational reasoning, proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, and combinatorial reasoning (Roadrangka, 1991). The Cronbach's alpha reliability coefficient of the GALT test derived for this study is 0.722.

Due to the Covid-19 pandemic, students were required to answer the GALT test via an online platform within a controlled one-hour session. Later, the results were analysed and recorded using descriptive analysis. Students who scored more than six points were categorised as high logical thinkers (HLT). Meanwhile, those who scored less than six points were considered low logical thinkers (LLT).

Upon completing the GALT online test, students were also required to state whether they have programming experience or not through an online background survey developed by the researcher. The online background survey was used to collect students' background information, such as their programming experience during school years and their examination results. Descriptive analysis was conducted, and the results are presented in tabular form in Section 4 of this article. Further analysis using Spearman Rho's correlation analysis was done to investigate whether or not the students' programming experiences have an influential factor in their logical thinking scores.

3.2 Investigating whether exposure to programming experience will impact students' cognitive skills in the long run

In the second phase, we conducted the linear regression analysis to predict whether exposure to programming experience will have a positive impact on students' cognitive skills or not. Students' programming experience was selected as the independent variable for this analysis. Meanwhile, logical thinking skill becomes the dependent variable. The result from this analysis is also presented in a tabular form in Section 4.

3.3 Proposing the gamified multimedia learning model for introductory programming

Finally, based on the theoretical framework discussed in Section 2.2 and correlation and regression analysis done in Sections 3.1 and 3.2, we proposed the gamified multimedia learning model by hybridising Mayer's segmenting principle of multimedia learning (Mayer, 2020) and Bedwell et al. (2012) game attributes, specifically in the categories of assessment and rules or goals. The idea is to construct instructional materials that best suit the programming learning environment for novice programmers. The game elements, also known as game mechanics, proposed in this model, are points or badges, levels, and progress bars.

4. Results and Discussion

This section discusses the results and analysis derived from this study, comprising descriptive analysis of GALT test results and students' programming experiences, correlation, and regression analysis to investigate the relationship between students' programming experiences and their logical thinking abilities. This section also discusses the proposed gamified multimedia learning model for introductory programming.

4.1 GALT Test Results

Table 1 below shows the descriptive analysis of the GALT test results. From ninety-seven students who participated in the online GALT test, it was revealed that only 47% of them were identified as HLT, while the other 53% were LLT. This result has proven the claims made by Mehmood et al. (2020) and Silva et al. (2020) that students at the beginners' level often lack and struggle with logical reasoning.

Table 1. GALT Test Results (HLT – High Logical Thinker/LLT – Low Logical Thinker)

		Frequency	Percentage
Valid	LLT	53	54.6
	HLT	44	45.4
	Total	97	100.0

Meanwhile, Table 2 shows the descriptive analysis of the number of students with programming experience. It was revealed that among ninety-seven participants of this study, only twenty-six students, or 26.8%, have programming experience. Meanwhile, over 70% of the students have never learned to program.

Table 2. Descriptive analysis of the number of students who have programming experience

	Frequency	Percentage
No experience	71	73.2
Experienced	26	26.8
Total	97	100.0

4.2 Correlation between Programming Experience and Cognitive Skills

Further analysis was done to investigate whether students' programming experience has an impact on their cognitive skills or not. For this matter, we have conducted Spearman Rho's correlation analysis, and the result is shown in Table 3 below.

Table 3. Correlation between programming experience and logical thinking levels

			Logical Thinking	Programming Experience
Spearman's rho	Logical Thinking	Correlation Coefficient	1.000	.654**
		Sig. (2-tailed)	.	.000
		N	97	97
	Programming Experience	Correlation Coefficient	.654**	1.000
		Sig. (2-tailed)	.000	.
		N	97	97

The statistical analysis has shown that programming experience has a moderate positive correlation with logical thinking levels at 0.654, significant at a p-value less than 0.05. This analysis leads us to conclude that students' programming experience can significantly affect their levels of logical reasoning.

4.3 Prediction of the Impact of Programming Experience on Cognitive Skills

The linear regression analysis was conducted to predict whether programming experience will significantly impact students' cognitive skills. The result from the model summary, as depicted in Table 4, has shown that the adjusted R squared scored 31.3% variance of the dependent variable, which means the independent variable explains logical thinking, that is, the programming experience.

Table 4. Model Summary, ANOVA, and Coefficients of the Linear Regression Analysis

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.566[a]	.320	.313	.415

a. Predictors: (Constant), Programming Experience

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	7.701	1	7.701	44.770	.000[b]
	Residual	16.341	95	.172		
	Total	24.041	96			

a. Dependent Variable: Logical Thinking
b. Predictors: (Constant), Programming Experience

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	.308	.047		6.507	.000
	Programming Experience	.172	.026	.566	6.691	.000

a. Dependent Variable: Logical Thinking

Further ANOVA analysis in Table 4 has also shown the significant value of $p < 0.05$, and the unstandardized coefficient for programming experience is 0.172, which explains that programming experience positively impacts logical thinking skills. This result also explains that the more students are exposed to programming experience, the better their logical thinking skills will be. This statement is also supported by previous research conducted by Halim and Phon (2020) and Thongkoo et al. (2022), which indicate that students' problem-solving abilities could benefit from exposure to more programming experience.

4.4 Proposed Gamified Multimedia Learning Model for Introductory Programming

Based on the theoretical framework discussed in Section 2.2 and statistical analysis derived from the previous phase, we proposed the gamified multimedia learning model that combines the multimedia learning principle with gamification elements.

The proposed model, as shown in **Fig. 1**, will also consider the instructional design model proposed by Tennyson and Rasch (1988), where the instructional strategies selected are problem-oriented strategies that use problem-oriented simulations. By adopting this strategy, the problem-oriented simulations will present situations requiring students to analyse the problem, construct the conceptual design of the problem, determine the problem's objective, and propose a solution to the problem. These are the steps considered suitable to be implemented in the learning programming context and have also been proven effective in enhancing students' logical programming thinking, resulting in higher learning success levels (Thongkoo et al., 2022).

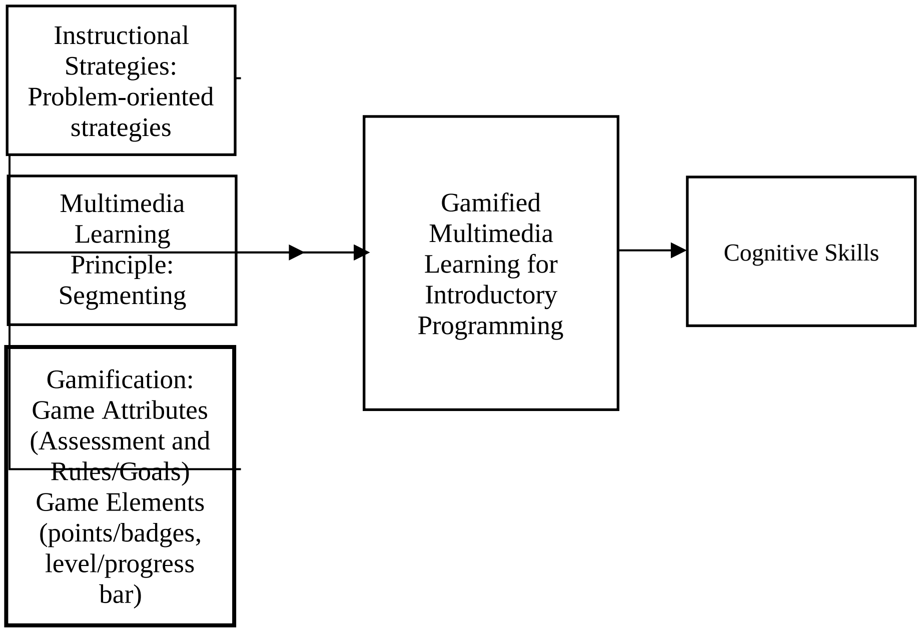

Fig. 1 Proposed Gamified Multimedia Learning Model for Introductory Programming

Meanwhile, for the selected segmenting principle of multimedia learning, as shown in **Fig. 1**, we proposed that the instructional material designed for introductory programming must allow students to learn according to their own pace, which is the leading theory behind segmenting principle (Mayer, 2020). In other words, the pace of the multimedia presentation, such as animation, should be flexible and can be controlled by learners, such as speed and navigating the lessons using "next" or "previous" buttons. It has been determined that a flexible and straightforward animation is practical and helpful in illustrating instructional roles, such as attracting and directing student attention (Lim et al., 2020). Furthermore, with the segmenting principle, instructors can divide their learning materials into segments, allowing learners to process information in small divisions adequately. With this, learners' cognitive load can be appropriately managed (Mayer, 2020).

Apart from that, gamification has also been selected to be embedded in the proposed model. Gamification, which can be defined as using game elements in a non-game context, can offer numerous advantages, such as enhancing students' motivation and engagement (Seman et al.,2019). For the proposed model, we have selected two categories of game attributes, as listed by Bedwell et al. (2012). The categories of game attributes selected are assessment and rules or goals. Bedwell et al. (2012) stated that via the assessment attribute, learners' accomplishments and progress could be tracked by game elements or game mechanics. The application of this attribute is consistent with students' requirements in learning programming, where they prefer to have features to track their progress and conduct self-evaluations (Sabjan et al., 2021). In addition, the type of game elements or game mechanics that can be utilised for this game attribute is points or badges, which will be rewarded to the students when each segment of task or problem is accomplished.

Meanwhile, for rules or goals attributes, the instructional material design must contain clearly defined rules and goals to be achieved by the player. Players, in this case, are students, should be given direction or information to progress towards the goal, a feature that is responsive to the needs of students for feedback and hints on their assigned tasks (Sabjan et al., 2021). The game elements or game mechanics that can be used for this category of a game attribute include a progress bar that displays the learner's progress for each segment or task and levels that display the learner's progress towards the learning materials' defined goals.

The gamified multimedia learning model proposed in this study aims to impact students' cognitive skills positively. This assumption is supported by all of the previously discussed theories, according to which the instructional learning materials should assist learners in managing cognitive load, as noted by Mayer's cognitive theory of multimedia learning. Moreover, Lander's gamified learning theory also proposed using game attributes that could influence learner behaviour or attitude, thereby enhancing the learning outcome.

5. Conclusion and Future Research

To summarise, this study sought to determine the effects of students' programming experience on their cognitive abilities, which resulted in the development of a gamified multimedia learning model for introductory programming. All the difficulties and issues encountered by novices when learning programming have underlined the importance of improving instructional technology. Particularly to address the learning requirements of students who lack cognitive abilities and problem-solving skills. Although numerous instructional tools have been developed and applied in the past to address this issue, integrating multimedia learning principles with gamification appears to be elusive. As a result, this study focuses on developing a gamified multimedia learning model tailored to the needs of novice programmers seeking to improve their cognitive skills.

Nonetheless, an analysis was undertaken to ascertain students' logical thinking skills, and a correlation was discovered between students' programming experience and logical thinking abilities. The correlation strongly drives us to predict whether increased programming experience results in an increase in logical reasoning abilities. Experiments conducted in this study produced statistically meaningful findings. As a result, we have determined that the gamified multimedia learning model should have a variety of components, including problem-based instructional methodologies, a segmenting principle for multimedia learning, and gamification with game attributes. The concept includes game mechanics such as points or badges, levels of progress bars highlighting learners' accomplishments, and a goal-oriented setting. Future studies will focus on developing a conceptual model of gamified multimedia learning that will be validated through user testing. This model is intended to assist learners in improving their cognitive abilities regarding problem-solving in computer programming.

6. Co-Author Contribution

The authors affirmed that there is no conflict of interest in this article. Mahfudzah Othman carried out the field work and was responsible for the writeup of the whole article. Dr Aznoora Osman prepared the literature elicitation and was involved with Ts. Dr Siti Zulaiha Ahmad in methodology and statistical analysis and results. Meanwhile, Assoc Prof Dr Natrah Abdullah carried out the theoretical framework and interpretation of the results.

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