Metacognitive Awareness Determination through Technology: A Problem-Solving Android Gamification App

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***Abstract*—This study was conducted to determine the learning outcomes of engineering students using android gamification application. Therefore, this study aimed to explore the Android gamification application grounded in a problem-solving approach to enhance metacognitive awareness. The objective of this study is to improve the digital and technological abilities of young individuals, while also fostering their cognitive and emotional preparedness for new educational prospects. A cross-sectional quantitative survey was conducted among 263 Electronics Engineering students in Higher Education who had accessed the Android gamification. Questionnaires were used to collect data, which was then analyzed using the Fuzzy C-Means Clustering approach, and Analysis of Variance (ANOVA). The study highlights that the team problem-solving approach, which incorporated game-like elements and mechanics, facilitated effective and creative collaboration among students. The results showed that the use of a problem-solving-based Android gamification significantly enhanced metacognitive awareness. Moreover, factors such as learning readiness and digital literacy had a positive impact. Perceived usefulness and the application ease of use were crucial mediators in the relationship between these factors and metacognitive awareness. This study provided practical insights by enriching engineering education methodologies through technology integration.**

***Keywords*—Android gamification, metacognitive awareness, learning readiness, digital literacy, engineering education**

I. Introduction

During this era characterized by swift advancements in technology and information, the educational paradigm is experiencing a significant transformation, commonly referred to as a substantial transition [1]. The fundamental objective of educational endeavors is to improve the quality of education and adequately equip students for the more intricate challenges of the modern world [2]. Consequently, there has been a strong emphasis on fostering innovative approaches to learning. In the contemporary globalized society, individuals are required to acquire advanced proficiencies, including but not limited to problem-solving aptitude, critical analytical skills, creative thinking abilities, and abstract reasoning capabilities, in order to achieve success [3, 4]. The understanding of metacognitive awareness plays a crucial role in the development of advanced skills [5, 6], as it directly impacts the capacity to learn new knowledge and regulate cognitive processes [7, 8]. Metacognitive awareness, as defined in the literature [9, 10], pertains to the capacity to comprehend, identify, and regulate one's cognitive processes. Furthermore, it aids students in effectively addressing challenges that may arise during their educational process and in comprehending the subject matter being presented.

Learning preparation refers to the capacity to effectively utilize technological advancements and cultivate advanced skills that align with the demands of the future labor market [11, 12]. Within the realm of electronics engineering education, the term "learning readiness" extends beyond the mastery of the academic curriculum. It involves a broader set of skills and attributes, including the capacity for independent study, critical thinking abilities, and the ability to adjust swiftly to dynamic circumstances [13, 14]. These skills empowered individuals the capacity to transcend conventional limitations, devise innovative resolutions to complex circumstances, and offer novel viewpoints on a range of obstacles [15–17]. High-level competencies encompass proficient communication, collaborative teamwork, and efficient time management [18]. These skills enable instructors to develop learning practices that are both pertinent and efficacious, while also equipping students with a robust groundwork on which to establish a prosperous future [19, 20].

Due to significant advancements in educational technology, the educational industry has experienced a shift towards prioritizing digital literacy [21]. The conventional structure of education has seen a significant transformation due to notable developments in the sector [22, 23]. The advancement of technology has not only facilitated the exploration of novel educational approaches, but it has also enabled the fostering of creative thinking and the incorporation of diverse methodologies in the process of acquiring knowledge [24–26]. Amidst the ongoing changes, there has been a growing significance attributed to the Android application that incorporates gamification as a means of enhancing the learning process [27, 28]. Recent research has revealed that the incorporation of game components, such as points, levels, and challenges, into educational activities for students has been found to enhance their motivation and participation in those activities [29].

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The objective of this study is to improve the digital and technological abilities of young individuals, while also fostering their cognitive and emotional preparedness for new educational prospects. Video games can enhance self-directed learning in students by offering a platform for individuals to actively apply and exchange their acquired knowledge. Furthermore, it is important to highlight that this specific opportunity enables individuals to actively engage in technical activities that exemplify the straightforwardness and usefulness of modern technology. Therefore, it is logical to investigate how learners are influenced and to inquire about the potential of skills in creating an engaging teaching approach through gamification? Can students' metacognitive awareness levels have an impact on problem-based learning? The statement explores the ways in which technology improves students' comprehension of advantageous elements. The aforementioned factors have the potential to enhance graduates' proficiency in technical problem-solving, critical thinking, and creativity. The research conducted exhibited certain limitations, including a restricted number of participants. Limited research has been conducted about the duration of study and the advantages associated with engaging in gaming activities. It focused on nurturing metacognitive awareness through a problem-solving approach implemented in Android gamification.

II. Literature Review

The proper implementation of gamification necessitates a significant degree of digital literacy. The concept of "digital literacy" encompasses a broad spectrum of competencies, encompassing the aptitude to proficiently operate diverse digital gadgets and software applications, among other proficiencies. The abilities stated above encompass critical thinking for the purpose of analyzing online content, problem-solving using technology, and virtual collaboration. Students who possess a comprehensive comprehension of digital literacy will possess the capability to fully utilize the gamification functionalities provided by Android programs [30, 31]. Students can engage to critically analyze challenges and assignments, select the most effective approach to achieve educational goals, and collaborate with peers using online platforms to achieve exceptional outcomes [32, 33]. Students could effectively resolve problems and accomplish tasks subsequent to conducting a comprehensive examination of those challenges. The widespread adoption of many advanced educational technologies has facilitated the realization of previously inconceivable opportunities, and they remain an essential element of any comprehensive and impactful educational framework.

Furthermore, it important to acknowledge that these competencies not only provide students with a solid basis for attaining success in their future pursuits [18–21], but they also empower educators to develop teaching strategies that are both pertinent and effective. The significance of recognizing these qualities as they provide pupils with a strong basis for achieving success in their future endeavors. Consequently, swiftly ascertain the individuals whose competencies are under scrutiny. The development and nurturing of these talents among students has great importance due to several reasons, which will be further upon in the subsequent paragraphs. The sector of education has witnessed a significant shift in focus towards prioritizing digital literacy due to the remarkable advancements made in educational technology. The rationale behind this phenomenon can be attributed to the remarkable advancements that have been achieved. Recent transformations can be attributed to a multitude of diverse sources. The conventional structure of education has undergone significant transformation due to notable breakthroughs in this field [22, 23]. This transformation has been instigated by a confluence of forces.

There is currently a rising emphasis placed on the incorporation of digital technologies into the educational framework of electrical engineering. In this context, the usage of Android gamification applications has shown itself to be an exceptionally effective tool for increasing digital literacy [34, 35]. The program has the power to provide educational experiences that are captivating and dynamic, while at the same time providing students with advanced technological capabilities [36, 37]. Participants who are currently enrolled in the program and actively engaged will be provided with the chance to enhance their digital literacy skills through a comprehensive framework that is applicable to real-life situations. This implies that the utilization of gamified learning environments facilitates the transmission of both academic knowledge and practical skills necessary for effectively utilizing technology in educational settings.

In order to fully harness applications as an effective educational tool, it is important to possess certain requisite skills and competencies. The curriculum places considerable focus on the acquisition of skills essential for effectively utilizing digital assets. An integral aspect of this endeavor entails educating students on the proficient utilization of diverse digital media formats and resources for academic purposes, alongside imparting skills for critically assessing the reliability and authenticity of online content. In addition, the use of gamification components inspires a spirit of healthy competition among the student. The use of leaderboards and awards has the ability to boost student motivation and encourage higher participation in learning tasks, which will ultimately lead to enhanced engagement in the learning process as a whole [38].

Educational technology has come a long way, the educational business has changed its focus to put more emphasis on digital literacy. Because of big changes in the field, the traditional system of education has changed in a big way [22]. The progress of technology has not only made it easier to try out new ways of teaching, but it has also encouraged creative thought and allowed people to use a variety of learning methods [23–24]. As things keep changing, the Android app that uses game-like elements to improve learning has become more important [27–28]. Students are provided with the opportunity for a more collaborative learning experience as a direct result of the exploitation of collaboration within the context of gamification, which in turn fosters the sharing of ideas and solutions. Students are given the opportunity to expand their digital literacy within a framework that is both comprehensive and practical when they make use of the program [39]. This involves the development of skills necessary for effectively employing technology as a tool for promoting learning and improving one's ability to use digital resources wisely. Moreover, it is crucial to develop the necessary skills and abilities that are vital for effectively utilizing technology as a tool to support and improve the educational experience [25]. As a consequence of this phenomenon, it is crucial to possess the requisite competencies. Students who are able to learn these skills, they will not only possess the capacity to effectively address technical challenges, but they will also possess essential proficiencies for succeeding in a more expansive digital age. Acquiring competence in these talents, they will not only possess the capacity to overcome technological challenges, but they will also be armed with fundamental abilities for attaining success in a constantly evolving digital age. learning readiness, digital literacy, perceived usefulness, ease of use, and meta-cognitive awareness should be taught [17, 40–42]. These skills are necessary for advanced electronics engineering. Android games help achieve this goal. This programmed boosts children's digital literacy and technology skills and prepares them emotionally for new learning. Video games let students self-evaluate their knowledge. They can also demonstrate technology's ease and usefulness with IT. This teaches students about technology's benefits. All of these factors may improve graduates' technical problem-solving, critical thinking, and creativity. By getting students involved in the development of new technology and making sure they are digitally relevant as engineering researchers or professionals, this project could help them learn how to solve hard engineering problems.

III. Methods

The research questions were formulated based on the established variables, namely Learning Readiness (LR), Digital Literacy (DL), Perceived Usefulness (PU), Perceived Ease of Use (PEU), and Metacognitive Awareness (MA) are all factors to consider. What is the cumulative impact of LR, DL, PU, PEU, and MA on the success of the gamification strategy in boosting students' engagement and learning outcomes? Moreover, what are the contributions of Fuzzy C-means clustering, and Analysis of Variance (ANOVA) in enhancing our comprehension of the correlations and effects of these variables within the framework of gamified learning environments? Fuzzy C-means clustering, and ANOVA were used in this work. The data sources and approach are presented in this section.

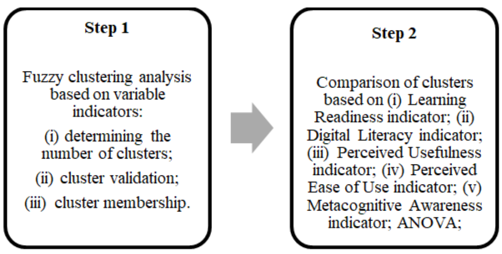

Fig. 1. Summary of methodological framework [43].

Fig. 1 shows that the first step is the analysis of Fuzzy C-means clustering to identify study clusters. ANOVA was carried out for the metacognitive awareness indicator. The cluster members were compared using tightness level indicators, presented through descriptive statistics, and ANOVA.

A. Participants and Procedures

This study was conducted a quantitative survey was conducted among 263 Electronics Engineering students in Higher Education who had used the Android gamification at the Faculty of Engineering, Universitas Negeri Padang. A non-probability sampling with random sample selection was also used. The profile of respondents is presented in Table 1.

Table 1. The profile of respondents

Sample Characterization		Number	Percent (%)
Age	> 24 years old	2	0.74
	23–24 years old	12	4.46
	21–22 years old	96	35.69
	19–20 years old	144	55.76
	17–18 years old	9	3.35
	Total	263	100
NIM/Student ID Number	2022	66	24.54
	2021	125	46.47
	2020	44	16.36
	2019	26	11.15
	2018	1	0.74
	2017	1	0.74
	Total	263	100
Major	Electronic Engineering	174	64.68
	Electrical Engineering	89	35.32
	Total	263	100
Duration of Smartphone Usage per Day	> 10 hours	124	46.1
	7–9 hours	56	20.82
	4–6 hours	39	14.5
	1–3 hours	44	18.59
	Total	263	100

Considering the data by age, 9 respondents (3.35%) fell into the 17–18 years age range, 144 (55.76%) were between 19–20, 96 (35.69%) between 21–22, 12 (4.46%) between 23–24, and 2 (0.74%) above 24 years. Based on Student ID/Registration Number, 1 respondent (0.74%) enrolled in 2017, 1 (0.74%) in 2018, 26 (11.15%) in 2019, 44 (16.36%) in 2020, 125 (46.47%) in 2021, and 66 (24.54%) in 2022. In terms of department, 174 (64.68%) majored in Electronics Engineering, followed by Electrical Engineering with 89 students. Regarding smartphone usage duration, 124 students (46.10%) used smartphones for more than 10 hours per day, followed by 56 (20.82%) with 7–9 hours, 39 (14.50%) with 4–6 hours, and 44 (18.59%) with 1–3 hours.

Prior to the experiment, respondents were informed about the goal and methods of the study and asked to indicate their willingness to participate. The respondents were subsequently instructed to access the "Android Gamification Based Team Problem Solving" application to understand the content related to resistors and capacitors in the application. The initial display of the application is shown in Fig. 2.

Fig. 2. The initial display of the application.

Students can input ID in the initial display to proceed to the next stage of the application. Fig. 3 presents the subsequent display. Students can make selection in the menu page, the “Start” button is used to access the content, while “Intro” is used to return to the initial page.

Fig. 3. The menu page of the application.

Fig. 4 presents the quiz page for the Resistor content, where students participate in a game related to resistors. The same approach applies to capacitors, as shown in Fig. 5. Students can proceed to view scores in the “Route Level” section, after completing the capacitor section.

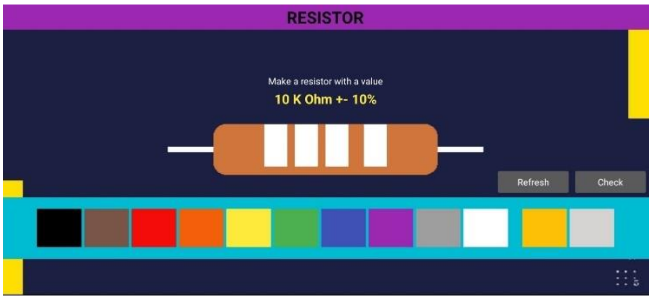

Fig. 4. The resistor game page.

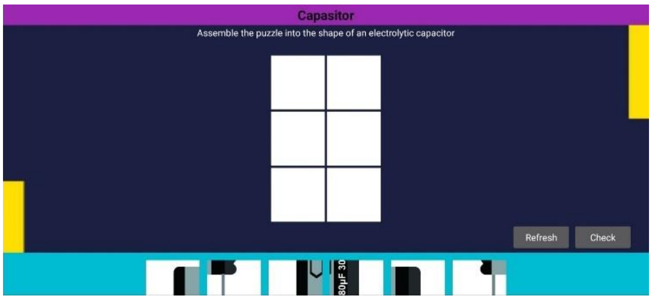

Fig. 5. The capacitor game page.

Fig. 6 presents the route level, where students can view the points earned by answering quizzes in the content. This feature helps in tracking progress while using the application.

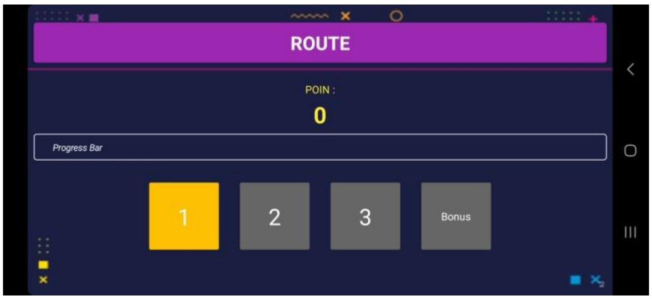

Fig. 6. Route level user.

B. Fuzzy C-Means Clustering Analysis of Every Indicator for Each Variable

Fuzzy C-Means Clustering analysis was conducted for each indicator in this step. This method uses a fuzzy partitioning approach to group data into several clusters based on specific similarities or characteristics [40–42]. It was developed by Jim Bezdek in 1973 and has been widely used in various fields, including the analysis of Higher Order Thinking Skills (HOTS) [44]. The primary objective was to group data into clusters that share similarities in certain features or characteristics while considering the degree of uncertainty or overlap in data grouping and study hypotheses [44, 45]. As a result, data were assigned membership levels reflecting the extent of relatedness to each cluster [46]. These membership levels can vary in a range of 0 to 1, allowing for overlap between clusters, which is a unique feature of Fuzzy C-Means Clustering method [47–49]. This characteristic is particularly suitable for cases of uncertainty or unit variability, where data cannot be definitively classified into one specific cluster due to complex and varying characteristics [50].

This current study used statistical software JASP version 0.1.7.1 to conduct Fuzzy C-Means Clustering analysis and investigate heterogeneity in determining the strongest clusters. The elbow method was utilized to estimate the optimal number of clusters, and the t-Distributed Stochastic Neighbor Embedding (t-SNE) was employed to assess the similarity between each cluster and its neighboring clusters.

C. Analysis of the Gender Indicator in HOTS Cluster Using ANOVA

This study was subjected to Analysis of Variance (ANOVA) in step three. This statistical approach was used to determine whether a significant difference in the means of two or more groups existed [51]. When there was a substantial difference between groups, a significant variation in means was discovered.

D. Instrument

The primary data collected were adapted from a structured questionnaire developed by several experts. The instrument included learning readiness, such as “I have motivation to learn” adapted from [52], digital literacy, such as “I am confident with my search and evaluation skills in regards to obtaining information using the Internet” from [40], perceived usefulness, such as “Using digital learning increases my productivity” from [41], perceived ease of use, such as “I find my digital learning with the system easy to use” from [42], and metacognitive awareness, such as “I ask myself questions about how well I am doing while learning something new” from [53]. The survey consisted of a total of 22 items, each accompanied by a set of response options. These possibilities included: (1) strongly disagree/never, (2) disagree/rarely, (3) unsure/occasionally, (4) agree/often, and (5) strongly agree/always.

IV. Result

Electronics Engineering education necessitated specific skills in the learning process of students. The selection of the appropriate skills in the learning process had a direct impact metacognitive awareness. Furthermore, the metacognitive awareness results were achieved by following the processes and stages mentioned in the study methodology section. In this stage, the average metacognitive awareness scores were presented in the form of Fuzzy C-Means Clustering, and ANOVA. The section below shows a detailed explanation of the analyses.

A. Fuzzy C-Means Clustering Analysis of Every Indicator in Each Variable

In the first step, Fuzzy C-Means Clustering to organize indicators into homogeneous groups, an analysis was performed. The Dunn index was used to determine cluster validity, and the elbow technique was employed to determine the number of clusters [54]. Subsequently, t-SNE map was used to visualize the high-dimensional map in low dimensions in order to validate the cluster solutions [55].

B. Determining the Number of Clusters

Fig. 7 depicts a graphical representation generated by the utilization of the elbow approach, which is commonly employed in clustering analysis to determine the optimal number of clusters for a particular dataset [56]. The primary objective is to identify the specific point on the graph that illustrates a substantial alteration in the extent of reduction in intra-cluster variance resulting from an escalation in the quantity of clusters. To achieve this objective, one can utilize indicators such as the Akaike Information Criterion (AIC), the Bayesian Information Criterion (BIC), and the Within-Cluster Sum of Squares (WCSS) [47]. The statistical criteria known as AIC and BIC are commonly employed to evaluate a range of statistical models, including clustering models with different numbers of clusters. These criteria aid in the selection of the most suitable model for accurately predicting the optimal cluster structure of the given data [48]. The statistical criteria referred to as the average information content and the minimum information content are well-established in the field. To avoid overfitting and increase model generalization, BIC prefers simpler models with fewer parameters [49]. Elbow plots show AIC, BIC, and WCSS values on the y-axis for various cluster counts on the x-axis. The number of clusters at the elbow position is chosen when the plot has an elbow-like form, a place known as the elbow point. Increasing the number of clusters above the elbow point has no discernible effect on AIC, BIC, or WCSS values. Fig. 7 depicts the graph used to determine the number of clusters.

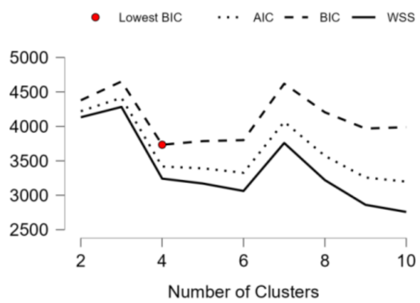

Fig. 7. Elbow method to determine the number of clusters.

Considering the first elbow point occurred at number four, the solution with four clusters was deemed the best and optimal alternative. Furthermore, Table 2 shows the AIC, BIC, and Silhouette indicators for the Fuzzy C-Means Clustering solution, which examined how well the data were consistently interpreted in the cluster.

Silhouette scores, ranging from –1 to 1, were maximized to achieve an optimal cluster solution, while BIC and AIC values were minimized. Table 3 provides additional evaluation metrics for the cluster solutions, including Pearson γ, Calinski-Harabasz index, Dunn index, and entropy.

Table 2. AIC, BIC, and Silhouette indicators of Fuzzy C-Means Clustering solution

Clusters	N	R^2	AIC	BIC	Silhouette
4	268	0.369	4276.500	4592.510	0.220

Table 3. Evaluation metrics of Fuzzy C-Means Clustering solution

Metrics	Value
Pearson γ	0.512
Dunn index	0.159
Entropy	0.674
Calinski-Harabasz index	38.061

Pearson correlation was determined for all pairwise distances against a vector of one and zero, where 0 denoted the same cluster category and 1 indicated distinct clusters, using the Pearson-measure. The Calinski-Harabasz index was developed by comparing the ratio of within-cluster variability to variability between clusters [54]. The Calinski-Harabasz index defines effective clustering as having the greatest proportion of cluster variation compared to within-cluster variation [52]. In other words, a higher value of Calinski-Harabasz index shows that the clusters are more separated from each other and more internally compact. Meanwhile, Dunn index is based on two important aspects of clustering analysis, namely cluster dissimilarity and maximum diameter, with the aim of measuring the quality of data partitioning [53]. It was evident that all evaluation metrics showed an increasing cluster density.

1) Cluster validation

The t-SNE method is a non-linear dimensionality reduction approach that may be used to visualize high-dimensional data in two or three dimensions [57, 58]. The major goal was to preserve relative structure by guaranteeing that data points that were comparable in high-dimensional space remained close to each other in low-dimensional space [59]. This is done by modeling the probability distribution using the distances between data points in the original high-dimensional space and those in the lower-dimensional space (where the data will be shown) [60]. Using unsupervised machine learning techniques, the bulk of the local structure in high-dimensional data may be captured by t-SNE while also revealing global patterns, including clusters at various sizes [61, 62]. The t-SNE plot for the cluster solution is shown in Fig. 8.

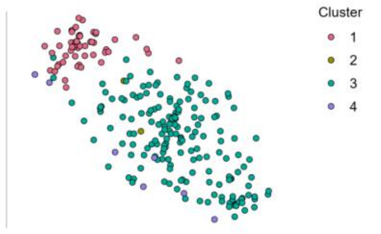

Fig. 8. t-SNE cluster plots for cluster solutions. Source: Study based on Eurostat data.

In the plot, the cluster members shown in different hues tend to be close to one other. This demonstrated the validity of the clustering solution, as members of clusters with identical or closely related traits were clustered together. In other words, data with shared characteristics were placed in similar clusters on the plot. A good clustering solution with cluster members on the plot had shorter distances among themselves but longer distances with other members. Therefore, the data were effectively grouped based on the similarity in characteristics, affirming the validity and reliability of the clustering solution.

The Fuzzy C-Means Clustering analysis was used to discover four clusters indicating skills in the Electronics way of learning. The findings revealed a significant level of similarity among the skills, implying interdependence and mutual influence during the learning process. This showed that a deeper knowledge of the relationships could help educators create more targeted and effective learning practices. The use of the elbow approach to calculate the ideal number of clusters verified Fuzzy C-Means Clustering analysis's ability in uncovering significant skill patterns. The results identified four clusters as the appropriate number to represent different skills in learning Electronics method [63].

Digital technology, such as the use of electronic circuit simulation and interactive software, plays a crucial role in aiding students gain a deeper understanding of technical concepts in Electronics learning. Digital literacy enables the effective use of these tools and maximize the benefits of available learning resources. Moreover, in the context of readiness for learning in cluster 3, digital literacy skills were relevant in assessing how prepared students were to engage in technology-based learning. Students with high levels of digital literacy were better equipped to handle learning demands related to technology, while those with lower digital literacy might require additional support to address such barriers, in accordance with [64].

C. Gender Indicator of Metacognitive Awareness Variable in HOTS Cluster Using ANOVA

Table 4 displays the ANOVA findings for the Metacognitive Awareness variable's gender indication.

Table 4. The ANOVA results indicate gender differences for the cluster solution

Cases	Sum of Squares	df	Mean Square	F	*p*
Gender	5.571	1	5.571	0.032	0.859
Residuals	46113.509	261	176.680		

Note: Type III Sum of Squares

The obtained *p*-value (0.859) was greater than 0.05, demonstrating that the average Metacognitive Awareness between males and females was relatively similar with no significant difference. Table 5 describes the indicators of Metacognitive Awareness.

Table 5. Descriptive-metacognitive awareness coefficient

Gender	N	Mean	SD	SE	Coefficient of variation
Female	62	55.661	14.211	1.805	0.255
Male	201	55.318	12.999	0.917	0.235

Out of the total number of respondents, 62 (24%) were females, while 201 (76%) were males. The standard deviation among females was 14.211, and 12.999 for males. The Standard Error of the mean for females was 1.805, and 0.917 for males. Furthermore, the Coefficient of Variation, representing the relative level of variability in the data, was 0.255 (25.5%) for females and 0.235 (23.5%) for males. Fig. 9 presents the Raincloud Plots of Metacognitive Awareness for both genders separately.

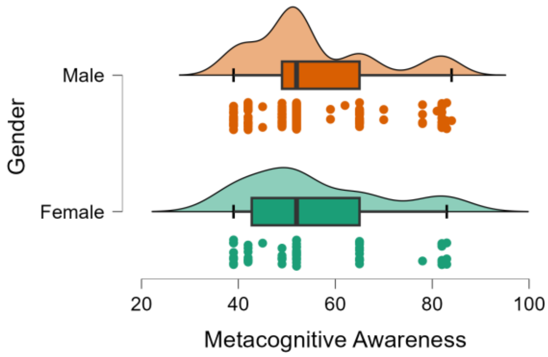

Fig. 9. Raincloud plots of metacognitive awareness.

Raincloud Plots offered insights into the distribution of data, dispersion, as well as the mean and median of Metacognitive Awareness for each group. Cloud plots represent data distributions, commonly referred to as "clouds", in the context of rainfall. A graphical representation that displays the density of the data distribution through a rotated and horizontally aligned kernel density estimate, resembling a violin plot. This plot provides valuable insight into the distribution of the data, effectively emphasizing regions of greater density. This result shows a better distribution of the data on females. Rain plots, as strip or swarm plots, are graphical representations of individual data points or raw data. In this plot, each data point is visually represented as a dot. These narrative segments present individual data points, offering a comprehensive view of the unprocessed data. When there is an extreme number of data points (repeated measurements), or a large number of waves, that makes the dot or density plot confusing and unexplainable. Boxplots are a commonly used graphical representation that displays the median and interquartile range. The descriptive plot shows that the "female" group subjects in metacognitive awareness had fewer counts compared to the "male" group, with confidence intervals barely overlapping.

Homogeneity Tests were carried out to examine whether the variances of two or more data groups differed significantly or not. The tests are essential in inferential statistics by relying on the assumption that the compared groups have similar variances. The results of the homogeneity tests are presented in Table 6.

Table 6. Test for equality of variances (Levene's)

F	df1	df2	*p*
1.565	1.000	261.000	0.212

The obtained *p*-value of 0.212, exceeding 0.05, indicated that the compared gender groups were the same or homogeneous. A greater confidence could be placed in the analysis results based on this assumption.

Fig 10. Q-Q plot normality showed that the data were normally and linearly distributed. The observations implied that the assumptions of normality and linearity required for ANOVA were not violated, and the results were valid, in accordance with [65, 66].

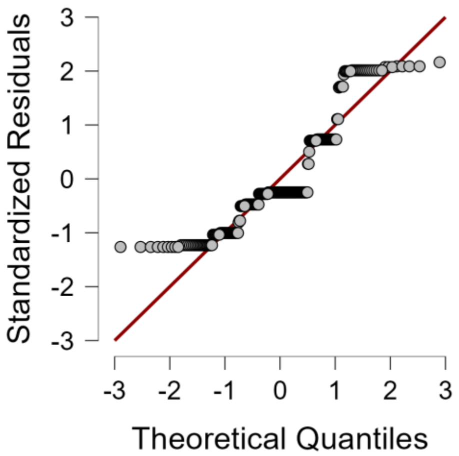

Fig. 10. Q-Q plot normality.

V. Discussion

This study demonstrated the efficacy of the gamification approach in motivating students, improving their ability to recognized digital resources, and promoting the use of reflective learning strategies. Integrating Android gamification has shown promise as a solution for improving digital literacy, learning readiness, and metacognitive awareness in students [40, 52, 53]. Furthermore, it bolstered these pivotal elements, resulting in a favorable improvement in metacognitive awareness within the realm of fundamental electronics education. The team problem-solving approach involves integrating game-like elements and mechanics into the collaborative problem-solving process on Android devices. Additionally, this encompasses attributes such as points, badges, leaderboards, challenges, and interactive scenarios to inspire team members to collaborate, perform efficiently, and exhibit creativity in resolving problems.

Choosing the best model to correctly guess the best cluster structure from the data requires considering the following [48]. E-learning developers must understand the statistical parameters known as the minimum and average information content. The above criteria are widely used in the field. BIC [49] found that learning experience designers should use simpler, lower-parameter models. This method will help the model generalize and reduce overfitting. Results showed that many skills were similar, suggesting they are connected and affect each other while learning. The above example illustrates the importance of understanding how things relate. This lets instructional designers create precise and effective learning strategies. Using the elbow method to determine the best number of clusters, we showed that Fuzzy C-Means Clustering can find interesting skill patterns. After reviewing the research, four clusters were chosen to demonstrate the wide range of skills in the Electronics learning method [65]. Real-world data from the research study led to the above conclusion.

The program effectively motivates students by using elements and dynamics similar to those commonly found in video games, such findings are also similar to findings from previous literature [29, 38]. Students were motivated to engage in a more dynamic way with the subject matter they were learning by incorporating various aspects, including points, badges, leaderboards, challenges and interactive scenarios. Video game-like elements and dynamics engaged students in the program. Points, badges, leaderboards, challenges, and interactive scenarios engaged students in the subject. Real-world evidence shows that gamification can help students recognized digital resources, supporting its effectiveness as a teaching method. Such findings show how the interactive part of the program encourages students to critically recognized digital media content.

As such, modern society is now able to identify reliable online sources among the many. The idea that students should actively critically analyze digital content supports the above idea. Gamification has increased student interest in reflective learning and participation. Based on evidence, gamification works well as a strategic instructional tool, which is in line with the findings of previous literature [27, 28]. The investigation shows that the comment accurately describes the situation. Teachers encouraged students to participate in gamified learning activities, which allowed them to reflect on their learning. The person has been given the chance to better understand the subject, and as a result, they can remember more. Furthermore, the implementation of gamification has played a significant role in improving students' ability to recognized the efficacy of digital resources. This finding demonstrates that the interactive feature of the program fostered a disposition among students to engage in critical examination and analysis of digital content, hence enhancing their ability to discern trustworthy information amidst the vast array of online resources. This assertion is substantiated by the observation that students actively participated in the process of critically evaluating and analyzing digital materials.

Based on the researcher's findings, it can be concluded that the application of gamification as an educational approach effectively motivates students to practice reflective learning, and this also adds to the evidence of some previous literature [30, 31]. The aforementioned statement reflects the inference derived from the findings obtained during the conducted inquiry. The students' active involvement in the gamified learning activities led to the chance for them to participate in self-reflection on their own learning processes, which was actively encouraged. Undoubtedly, this intervention facilitated the learner in attaining a deeper understanding of the subject matter and enhanced their ability to retain the acquired knowledge.

Digital technology is an important part of teaching electronics because it gives students access to many tools that help them fully understand technical ideas. The use of electronic circuit simulation is an example of a tool, that students can simulate and study circuits in a virtual world with this software application, and this finding adds to the evidence of some previous literature [25, 30]. This lets people learn by doing by letting them change the way circuits are set up and then watch the behavior that happens as a result of their experiments. Interactive software also has fun activities and exercises that are meant to help students understand concepts better and get them involved. This event makes the process of learning better and adds to the overall improvement of learning. The use of digital resources in electronics classes can really help students understand complicated technical ideas better, which can lead to big improvements in their understanding. Learning digital literacy is an important skill that lets people use a wide range of tools well and get the most out of the educational resources that are available to them.

The utilization of diverse analytical techniques, such as Fuzzy C-Means Clustering, and ANOVA, has led to significant findings on the intricate dynamics of interactions among the variables comprising the learning context. The aforementioned findings were acquired through the examination and analysis of the data generated by the aforementioned methodologies. The present study significantly contributes to the advancement of educational methodologies aimed at enhancing students' competencies in addressing challenges within the dynamic field of engineering.

VI. Conclusion

Ultimately, this research extends the importance of metacognitive awareness in the context of engineering education and presents an innovative way to enhance this element. The use of Android gamification based on a problem-solving framework shows the potential to impact metacognitive awareness positively. The results show the importance of learning readiness and digital literacy in fostering such awareness. In addition, perceived usefulness and perceived simplicity of use mediate in linking these factors with metacognitive awareness showing important contributions. This study offers practical insights for educators and institutions that prioritize innovative strategies to improve engineering students' thinking skills. Technology integration, particularly through gamification, offers a promising avenue to foster metacognitive awareness, thereby contributing to the quality of education. As education evolves, the utilization of technological tools can shape a more effective and engaging learning environment, equipping students with skills that go beyond field-specific knowledge.

This study demonstrates the efficacy of gamification in cultivating students' motivation, improving their skills in recognized digital resources, and encouraging reflective learning practices. Nevertheless, it is important to remember that there are certain limitations. In addition, it is plausible that the investigation was conducted in a specific educational setting or with a limited number of participants. Either of these criteria could potentially affect the extent to which the findings can be extrapolated to a wider population of students. In addition, the duration of the study and the sustained efficacy of the perceived benefits of the gamification approach were not adequately investigated, leading to potential uncertainty regarding the long-term impact of the intervention even over a considerable time.

Future research is recommended to investigate the long-term impact of the application on metacognitive potential variations across different engineering disciplines. Investigating the mechanisms by which gamification triggers metacognitive processes can provide valuable insights into the underlying dynamics of thinking. This study builds a foundation for innovation that incorporates technological solutions to address the issue of metacognitive awareness in engineering education, demonstrating its role in fostering holistic and adaptable engineering professionals.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Hendra Hidayat: Concept and design, Supervision, Drafting manuscript. Zamzami Zainuddin and Jem Cloyd M. Tanucan: Data acquisition, Critical revision of manuscript. Yuni Rahmawati and Muhammad Anwar: Technical and material support, Supervision. Hadi Kurnia Saputra: Drafting manuscript, Statistical analysis. Elsa Sabrina: Collecting Data, Statistical analysis. All authors had approved the final version. All authors approved the final version.

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