The Influence of Gamification-Based Assessment on Student Learning Outcomes through a Mobile Web Application

Reni Rahmadani[1,*], Tansa Trisna Astono Putri[1], Muhammad Dominique Mendoza[1], Olnes Yosefa Hutajulu[1], and Elsa Sabrina[2]

[1]Department of Electrical Engineering Education, Faculty of Engineering, Universitas Negeri Medan, Medan, Indonesia
[2]Department of Family Welfare Education, Faculty of Engineering, Universitas Negeri Medan, Medan, Indonesia
Email: renirahmadani@unimed.ac.id (R.R.); tansatrisna@unimed.ac.id (T.T.A.P.); aenaen@unimed.ac.id (M.D.M.); olnes.hutajulu@unimed.ac.id (O.Y.H.); elsasabrina@unimed.ac.id (E.S.)
*Corresponding author
Manuscript received November 15, 2024; revised December 26, 2024; accepted February 1, 2025; published August 18, 2025

***Abstract*—This study aims to analyze the effect of applying the experimental demonstration method on student learning outcomes in understanding the concept of adsorption. The research sample consisted of 107 students divided into four classes, with classes A and B as experimental groups and classes C and D as control groups. Data were collected through pre-test and post-test to evaluate changes in students' understanding after learning. Normality analysis using Shapiro-Wilk test showed that the data were normally distributed. The results of the variance homogeneity test with the Levene test showed that the variance between groups was homogeneous. The paired t-test was used to test the difference in learning outcomes, with a significance value (*p*-value) for the experimental class of 0.000, which indicates a significant effect of the treatment given. In contrast, the control class showed a significance value of 0.081, which means there is no significant difference. The conclusion of this study is that the experimental demonstration method is effective in improving student learning outcomes, so it can be recommended as a useful learning method in the context of science education. This research also provides a foundation for further studies on other learning methods that can be applied to improve students' understanding in various subject areas.**

***Keywords*—gamification, assessment, mobile web development, learning outcomes, educational technology**

I. Introduction

Digital technology is playing a key role in the transformation of education, driving innovations that change the way teaching and learning is done. Through the application of game elements in an educational context, gamification provides opportunities for students to be actively involved in their learning process [1]. Therefore, the context of this research focuses on the impact of gamification in education and its effectiveness in improving student motivation and learning outcomes in the Computer Security Systems course (hereafter SKK). Changes in educational technology today require educators to adopt new methods that are not only engaging, but also capable of facilitating a deep understanding of complex issues in cybersecurity [2, 3]. This research aims to identify the direction of development in integrating gamification, including in curriculum development, crafting innovative teaching methodologies, and measuring the impact on students' learning experience.

The age of digitization enables the dissemination of knowledge and skills through interactive platforms that facilitate collaborative learning [4]. This process accelerates technology adoption among students, which is becoming increasingly important in the context of the need for cybersecurity skills in a connected world [5]. Therefore, this research underscores the importance of developing students' digital skills, given the ever-changing demands of the industry. In this context, educators have a great responsibility to prepare students to meet new challenges, which involves a solid understanding of the concepts of information security and data protection [6]. Gamification emerges as a promising strategy in this context, utilizing game elements to stimulate student interest and engagement in learning.

The main focus of this research is how gamification can be effectively implemented in the SKK course to develop students' competencies in dealing with evolving cyber threats. The key question that arises is: "how can game elements be integrated into the curriculum to create a more interactive and impactful learning experience?". Answering this question is critical to increasing student engagement and ensuring that they acquire relevant knowledge and skills for their careers in cybersecurity.

Hellín *et al.* (2023) [7] shows that gamification can increase student motivation and engagement in various educational contexts. In addition, research by Chans and Portugez Castro, (2021) [8] underlines the importance of gamification in improving learning outcomes, especially in higher education. While there are various studies addressing the application of gamification in educational contexts, this research will highlight the need to develop a gamification model specific to the SKK course, which takes into account the unique characteristics of the content and competencies to be mastered by students. The novelty in this research lies in the development of a gamification model that focuses not only on increasing student motivation, but also on mastering practical competencies in computer security. This research will integrate the latest technologies, such as interactive simulations and game-based learning elements, to create an immersive learning experience. In addition, this research will evaluate the impact of implementing the gamification model on student learning outcomes quantitatively and qualitatively, which is expected to make a new contribution to the development of teaching methods in the field of cybersecurity.

Finally, although research on the influence of information technology and gamification in education has been conducted, there is still room for further exploration. In this context, it is important to understand how educators can adapt their teaching strategies to make the most of the potential of information technology and gamification. The question of implementing effective and relevant evaluation methods also needs to be explored further. Further research in this area can make an important contribution to creating educational

doi: 10.18178/ijiet.2025.15.8.2365

approaches that are more responsive and adaptive to the rapidly changing world of education.

II. LITERATURE REVIEW

Technological globalization and innovations in education encourage the adjustment of teaching methods to be relevant to social and economic developments [9]. This process also requires educators to explore new approaches that can help students understand complex concepts in computer security [10]. In this study, the authors aim to develop a gamification model designed to support learning in the SKK course, and evaluate its impact on student motivation and academic achievement. Through an interdisciplinary approach, this research seeks to identify key components of gamification that can be applied in the teaching and learning process. Technological advances open up new opportunities in the way we teach and learn information, but also present challenges, such as the need to improve students' critical and creative skills [11]. Education must find innovative solutions to overcome these challenges, while remaining committed to a diversity of approaches to teaching [12]. The practical significance of this research lies in the application of gamification as a tool to develop skills required in the digital age, particularly in the context of cybersecurity.

Cybersecurity has become an increasingly important field in line with the rapid development of digital technology and interconnected systems in cyberspace. In the context of education, particularly in courses related to cybersecurity, the application of gamification offers an innovative approach to enhance students' understanding and skills in facing online threats [13]. Gamification, which involves incorporating game elements into non-game contexts, can motivate students to engage more actively in learning about cybersecurity [14]. By using game simulations that reflect real-world situations in cybersecurity, students can learn about cyber threats, data protection, and mitigation strategies through interactive experiences. This allows students to not only understand the theory but also hone the practical skills needed in the real world.

Through gamification, complex concepts in cybersecurity, such as encryption, network protection, and cyberattacks, can be delivered in a more engaging and easily understandable way. Additionally, game elements like challenges, scores, and levels can increase students' motivation, encouraging them to put in more effort and achieve a deeper understanding [15]. In this way, gamification not only enriches the learning experience but also prepares students to face challenges in an increasingly digital and interconnected professional world, especially in its application in the 21st century.

The 21st century is characterized by rapid advances in information and communication technologies, which have had a significant impact on education [16]. Amidst globalization, the application of innovative technologies in education serves as a key enabler for achieving optimal outcomes [17]. The application of gamification in the SKK course plays a vital role in strengthening students' understanding of best practices in maintaining information security, as well as equipping them with the skills needed in an increasingly competitive world of work.

Gamification in education is grounded in several theoretical frameworks that explain how it can enhance learning outcomes. One of the key theories is Self-Determination Theory (SDT), which posits that people are most motivated when their basic psychological needs for autonomy, competence, and relatedness are satisfied [18]. In the context of gamification, elements like points, badges, and leaderboards provide external rewards that fulfill students' need for competence and relatedness. When these elements are used to support intrinsic motivation, they can lead to increased engagement and better learning outcomes [19]. Additionally, gamification taps into the Flow Theory by Csikszentmihalyi (1990) [20], which suggests that people achieve optimal learning and performance when they are in a state of flow—an experience characterized by a perfect balance between challenge and skill. Gamified elements like progressing through levels and receiving real-time feedback can help students achieve this state by offering challenges that are appropriately matched to their skills, thereby enhancing focus and motivation. Another important theoretical foundation is Behaviorism, which emphasizes reinforcement as a method to encourage desired behavior. In gamification, frequent rewards and feedback serve as positive reinforcement, which can motivate students to continue their engagement and persist in their learning tasks [21]. By combining these theories, gamification creates an environment that encourages active participation, increases motivation, and fosters a sense of achievement, all of which contribute to improved learning outcomes.

While advances in education and information technology have created new opportunities, there are still fundamental challenges in adapting the learning process to meet modern-day needs [22]. For example, how can educators adapt their approach to deal with the ever-changing dynamics in curriculum and teaching methods? What is the role of collaboration between educators, students and other stakeholders in creating a more inclusive and responsive learning environment?

Interpersonal skills and the ability to work in diverse teams are increasingly important in the context of 21st century education. Ongoing research is needed to explore strategies that can improve collaboration and interaction between all parties involved in education [23]. This investigation includes identifying best practices and innovative approaches that have proven effective in enhancing students' learning experiences. This research not only contributes to a deeper understanding of the dynamics of learning, but also creates a framework for better professional development of educators in a global context.

In an effort to prepare students for an increasingly complex world of work, it is important for educators to instill the cognitive and affective skills needed to face future challenges [24, 25]. In this information age, mastery of information technology is not just an advantage, but a basic necessity for students [26]. Therefore, an emphasis on skills such as critical thinking, problem-solving and adaptability is highly relevant in the education curriculum [27]. Education must be able to address these challenges in a way that is relevant and engaging for students, to ensure that they are prepared for the evolving demands of the job market.

Taking into account the need for relevant skills and innovative approaches in education, this research seeks to identify ways to implement gamification in the teaching of

SKK. The question that arises is: how can gamification be used to increase student engagement and develop practical skills required in the field of cybersecurity? This research is expected to provide new insights into the integration of gamification in higher education, as well as contribute to the creation of more engaging and effective learning experiences.

III. Methods

A. Research Design

To assess the effectiveness of the development of gamification-based mobile web assessment in learning in the Information and Computer Technology Education Study Program, this study uses a quantitative approach with a quasi-experimental design as the main methodology. The theoretical framework in this study refers to the education-based technology development model that emphasizes the role of technology as a tool to increase active participation and engagement in learning [28]. Based on this theory, this study formulates the hypothesis that the application of gamification in evaluation will improve students' learning motivation and academic performance.

The quasi-experimental design used involved two groups, a control group and an experimental group, with pre-test and post-test measurements to assess significant changes in learning outcomes [29]. The pre-test was used to measure students' initial knowledge, while the post-test measured progress after the implementation of gamification in the learning process [30]. This approach allows for a more in-depth analysis of how technological interventions, particularly gamification, affect learning effectiveness [31]. A challenge in this study was the impossibility of randomly assigning the control and experimental groups, as the class distribution had already been determined prior to the study. Nonetheless, a quasi-experimental design was chosen as it still allows the researcher to measure the effect of the intervention with high validity.

This research method also considers the important role of the interaction between students and the gamification-based evaluation system, which is believed to encourage deeper learning engagement, as well as strengthen the understanding of complex concepts in the SKK course.

B. Participants

This study involved 107 sixth semester students in the 2023/2024 academic year who were divided into 4 classes: A, B, C, and D, with each class consisting of 25–30 students. Classes A and B will be the experimental group, while classes C and D will be the control group. In addition, the needs analysis process for the website involved 4 lecturers and 20 randomly selected students from the Information and Computer Technology Education Study Program.

C. Procedure

This research involves a series of stages that are systematically designed to ensure that the resulting system is not only relevant to user needs, but also effective in supporting learning. These stages include needs analysis, web design, application development, classroom implementation, learning process with experimental and control methods, and evaluation and analysis of results.

Fig. 1 illustrates the research procedure for the development of a gamification-based assessment system through mobile web, which is divided into six stages. First, needs analysis was conducted through surveys and interviews with lecturers and students to identify expectations of the system. Second, web design focused on creating attractive features and interfaces. Third, the development stage includes application construction and initial testing. Fourth, classroom implementation divides participants into experimental groups using gamification and control groups using conventional methods. Fifth, the learning process takes place with a pre-test to measure initial knowledge, a learning session, and a post-test to evaluate knowledge improvement. Finally, data evaluation and analysis were conducted to assess the effectiveness of the gamification system using statistical techniques. Overall, Fig. 1 shows a systematic methodology in evaluating the effectiveness of a gamification-based assessment system in an educational context.

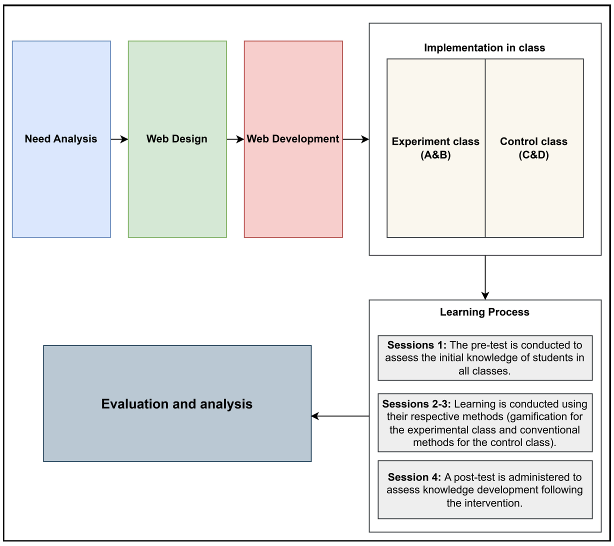

Fig. 1. Research procedure flowchart.

The gamification elements incorporated into the assessment system were strategically selected to maximize engagement and motivation while maintaining a clear focus on educational objectives. From a range of potential features, quizzes, badges, and leaderboards were identified as the most effective and impactful for achieving the desired outcomes within the learning environment. Quizzes serve as the foundation of the gamified assessment system, transforming traditional evaluation methods into interactive learning experiences. This approach provides immediate feedback, helping students monitor their progress and identify areas for improvement in real-time. It not only strengthens understanding of the material through repetition but also encourages active engagement and promotes self-directed learning behaviors.

Next, badges were chosen for their ability to provide additional motivation by serving as symbolic rewards for student achievements. These visually appealing badges are awarded when students reach specific milestones, such as achieving high scores or completing challenging tasks. Finally, leaderboards introduce an element of healthy competition that motivates students to perform at their best while fostering a sense of community and collaboration. Customization features ensure inclusivity, allowing students to compete individually or in supportive small groups, creating an environment that accommodates diverse learning preferences.

The decision to focus exclusively on quizzes, badges, and leaderboards reflects a deliberate effort to balance simplicity with effectiveness. These elements are not only easy to implement and navigate but also directly align with the system's core goal of enhancing learning outcomes. By avoiding overly complex or extraneous features, the system ensures that students remain focused on their learning objectives without unnecessary distractions. Additionally, this streamlined approach ensures scalability and adaptability, making it easier to refine or expand the system based on user feedback and evolving educational needs.

D. Data Collection

Data collection was conducted through pre-test and post-test at the beginning and end of the learning session. The pre-test was conducted to measure students' initial knowledge of computer security before the intervention, while the post-test was conducted after the learning session to evaluate the progress of the knowledge gained. Each test consisted of questions related to the topic taught and was scored with a maximum of 100 points. After testing, lecturers involved in the study will collect and process the test result data, assigning grades based on predetermined criteria. The final procedure involves calculating the average score for each group, both experimental and control, to analyze the impact of the gamification system on improving students' knowledge.

E. Data Analysis

Data analysis was conducted by calculating the frequency, percentage, and average pre-test and post-test scores of each group. In this study, a t-test was used to determine whether there was a significant difference between the experimental group using the gamification system and the control group using conventional methods. This study also applied the regression analysis method to evaluate the effect of the gamification system on improving students' knowledge in computer security systems. Thus, this analysis aims to provide a deeper understanding of the effectiveness of gamification systems in learning contexts.

IV. Result and Discussion

A. User Analysis

This research resulted in the development of a gamification-based mobile web assessment for students of the Information and Computer Technology Education Study Program. This platform not only functions as an assessment tool, but also as a means to increase student involvement in the learning process. However, the implementation of gamification in this learning is not enough to fully guarantee the improvement of students' understanding of the material taught. Despite the increase in interest and participation, the results showed that the increase in student learning outcomes only reached 40.15%. This shows that although gamification succeeded in attracting students' attention, more comprehensive learning methods are still needed to ensure deeper understanding. As a result, the level of student competency achievement in related courses has not reached the expected target.

B. Design of a Gamification-Based Assessment Mobile Web

This section describes the design of the mobile web designed to support the gamification-based assessment process. The development of this system aims to increase student motivation and engagement in learning, as well as provide a more interactive and engaging evaluation tool. The web design is based on the results of the analysis of user needs, namely lecturers and students, and considers gamification elements such as awarding points, badges, and leaderboards to motivate learners. The interface is designed to be easy to use, responsive and intuitive so that users can easily access and complete assessment tasks. The following is a visual display of the developed gamification-based assessment mobile web design.

Fig. 2 shows the interface of the gamification-based assessment mobile web. In the first image (left), there is a login page where users, in this case students, have to enter their email and password to access the system. At the bottom are options to recover a forgotten password and to create a new account. In the second image (on the right), upon successful login, students are greeted with a personalized motivational message displaying their username. There are several main navigation buttons consisting of "Quiz", "Profile", and "Logout". This feature makes it easy for students to directly access the quizzes provided, view their profile, or log out of the system. In the gamification framework, quizzes are an essential tool for providing instant feedback, which is a crucial aspect of increasing engagement [32]. By offering various types of questions (fill-in, multiple-choice, and sorting), quizzes not only test students but also introduce different levels of difficulty, encouraging internal competition. This motivates students to continually strive to master the material.

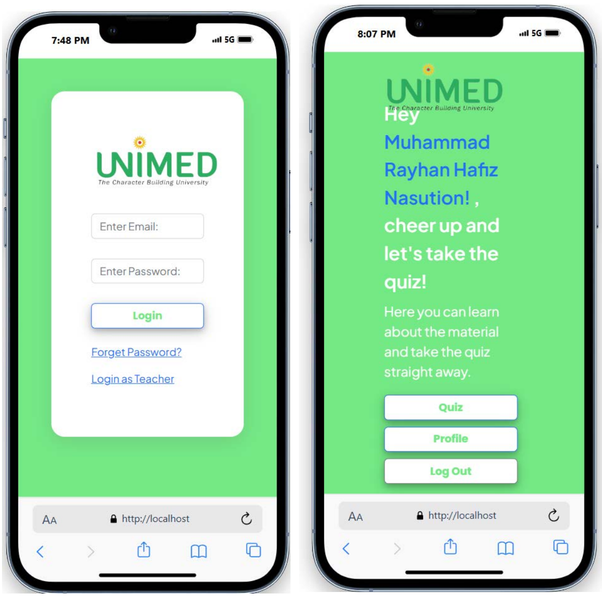

Fig. 2. The main menu of game gamification-based assessment mobile web.

This simple and user-friendly interface design makes it easier for students to interact with the application and encourages active participation in gamification-based learning.

Fig. 3 shows three types of quizzes available on the gamification-based assessment mobile web. First, a fill-in quiz, where students are asked to answer 10 questions by filling in the answers directly. Second, a multiple-choice quiz consisting of 10 questions, where students choose the most appropriate answer from several available options. Third, the sort quiz, where students have to arrange the answers to the questions given in a randomized form. Each type of quiz has a clear "start" button to initiate the quiz and brief instructions that encourage students to do well. The user-friendly interface and attractive illustrations make it easier for students to understand and work through each type of question, providing a more interactive and enjoyable learning experience.

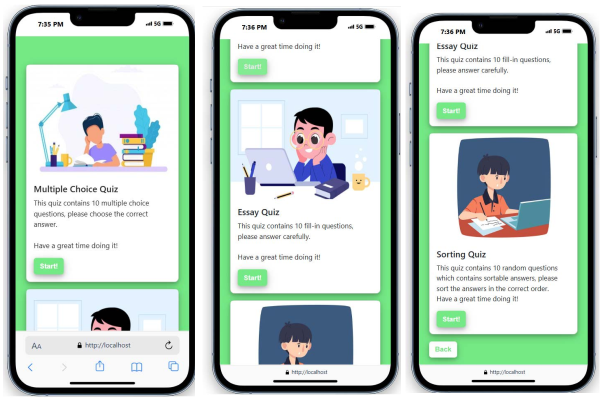

Fig. 3. Quiz page.

Fig. 4 displays the quiz results page on the gamification-based mobile web assessment. In the first display, students are notified of the number of questions that have been successfully answered along with the score obtained, such as "You successfully answered 4 out of 5 questions, Your score: 80.00." The second display shows a motivational message informing-students that they have completed the quiz and the score obtained, with the option to retake the quiz or complete it. Leaderboards, on the other hand, add an element of social competition, allowing students to compare their performance with that of their peers.

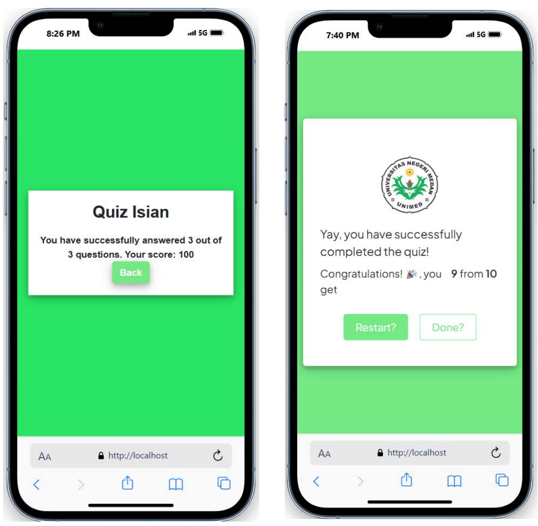

Fig. 4. The result of quiz page.

In Fig. 5, leaderboards are highly effective in fostering healthy competition, motivating students to improve their scores and achieve higher rankings. Badges are a gamification element that provides visual rewards for specific achievements or skills. The presence of badges offers external motivation within gamification, reinforcing positive behaviors such as completing quizzes or achieving learning goals. These visual rewards recognize student accomplishments, motivating them to continue their learning journey and strive for further achievements. By providing a broader context of their progress, leaderboards encourage students to perform better. In the third view, the student profile page is displayed, containing important information such as name, class, and history of quizzes taken, complete with a score progression graph of each quiz taken. This makes it easy for students to track their performance over time.

Fig. 5. The result of leaderboards page.

C. The Results of a Gamification-Based Assessment Mobile Web Data Analysis

1) Normality test

Statistical tests that can be used include the Chi-square, Kolmogorov-Smirnov, Lilliefors, Shapiro-Wilk, and Jarque-Bera tests. The Chi-square test tests hypotheses about the relationship between two categorical variables by comparing observed and expected frequencies [33]. To qualify, data must be in categorical or nominal form, with an expected frequency of at least five for each category and no more than 20% of categories with frequencies less than five. In addition, the observations must be independent [34]. The Kolmogorov-Smirnov (K-S) test checks whether the sample distribution comes from a particular distribution, such as normal, by comparing the observed and expected cumulative distributions [35]. The data must be independent and can be measured on an ordinal or interval scale [36].

The Lilliefors test, as a variation of K-S, is suitable for small to medium sizes without known distribution parameters, with the same conditions [37]. The Shapiro-Wilk test tests the normality of the data and is more sensitive to small to medium samples, provided the data must be independent and measured on an interval or ratio scale [38]. The Jarque-Bera test assesses the normality of the distribution based on skewness and kurtosis, ideal for large samples [39]. Conditions also include independence of observations and measurement on an interval or ratio scale. Therefore, the absolute value of this parameter is measured based on the deviation of the distribution from normal. However, the Jarque-Bera test is not available in statistical software such as SPSS, Minitab, or STATA.

This study presents normality calculations on pre-test and post-test data of students who have taken part in learning with gamification-based experimental methods. The normality test used is the Shapiro-Wilk test, which was chosen because it is suitable for small samples (<100), according to the number of students per test class (25–30 students per class). The results of the normality test are presented in Table 1. To determine whether the data is normally distributed using Shapiro-Wilk, simply look at the significance value (sig.) or *p*-value in the Shapiro-Wilk column. If the *p*-value > 0.05, H0 is accepted which means the data is normally distributed. However, if the *p*-value < 0.05, H0 is rejected which means the data is not normally distributed. The hypotheses tested in this study are: i) Pre-test and post-test data are normally distributed (H0); ii) Pre-test and post-test data are not normally distributed (H1).

Table 1. The result of normality test

Respondent		Kolmogorov-Smirnov[a]	Shapiro-Wilk
		Statistic	**df**
Pre-test	Class A	0.123	25
	Class B	0.125	30
Post-test	Class A	0.098	25
	Class B	0.105	30

[a]Lilliefors Significance Correction.
df: degrees of freedom

Based on Table 1, it can be seen that the results of the normality test using Kolmogorov-Smirnov show a statistical value of 0.123 for class A and 0.125 for class B in the pre-test, and 0.098 for class A and 0.105 for class B in the post-test. The degrees of freedom (df) values are 25 for class A and 30 for class B, which indicates the number of samples used in this study.

These statistical values indicate the calculation of the Kolmogorov-Smirnov coefficient used to compare the distribution of the data with the theoretical normal distribution. The smaller the statistical value, the closer the sample distribution is to the normal distribution. With these values in mind, the next step is to check the significance (sig.) to determine if the data is normally distributed. If the significance value is greater than 0.05, then the data accepts the null hypothesis (H0), which means the data is normally distributed. The manual calculation process for the Kolmogorov-Smirnov test is rarely done because it involves a lot of complex computations, so statistical software is usually used to facilitate the analysis. Once the normal distribution of the data is confirmed, a homogeneity test can be performed to proceed with further statistical testing, such as the t-test or variance test.

2) Homogeneity test

To test for homogeneity, we can use the Levene test or Bartlett's test, depending on the number of data groups being compared. The Levene test is used to determine whether two data groups have equal variances, without requiring the assumption of normal distribution, though the data must be continuous [40]. Bartlett's test, on the other hand, is used to check for homogeneity of variances across more than two data groups [41]. In this study, the Levene test was chosen because it is relevant for testing homogeneity between two groups. The results of the homogeneity test are shown in Table 2.

Table 2. The result of normality test

		Levene statistic	df1	df2	sig.
Pre-test	Based on mean	1.042	1	105	0.310
	Based on median	0.085	1	105	0.771
	Based on median and with adjusted df	0.085	1	78.103	0.771
	Based on trimmed mean	0.925	1	105	0.338
Post-test	Based on mean	0.002	1	105	0.963
	Based on median	0.003	1	105	0.960
	Based on median and with adjusted df	0.003	1	80.259	0.960
	Based on trimmed mean	0.002	1	105	0.963

df: degrees of freedom

Based on Table 2, the results of the homogeneity test using Levene's test indicate that the variances between the control and experimental groups in both the pre-test and post-test data are homogeneous. In the pre-test, the significance (sig.) value based on the mean is 0.310, while the value based on the median is 0.771, and based on the trimmed mean, it is 0.338. All these values are greater than 0.05, indicating that the variance in the pre-test data between the two groups is homogeneous. In the post-test, the sig. value based on the mean is 0.963, based on the median is 0.960, and based on the trimmed mean is also 0.963. These values are well above 0.05, confirming that the variance in the post-test data between the control and experimental groups is also homogeneous. Therefore, it can be concluded that the variances between the two groups, for both pre-test and post-test data, are homogeneous. This homogeneity of variances meets one of the key assumptions before proceeding with further statistical analysis, such as the t-test.

3) T-test calculation

The prerequisites for conducting a t-test in this study, namely that the data must be normally distributed and have homogeneous variances, have been fulfilled based on the results of the normality and homogeneity tests. Therefore, the t-test can be conducted to compare the pre-test and post-test results between the control and experimental classes. If the normality and homogeneity assumptions had not been met, non-parametric mean difference tests, such as the Mann-Whitney or Kruskal-Wallis tests, could have been applied. However, since the assumptions are satisfied in this study, the t-test can proceed.

The t-test was conducted separately for the control and experimental classes, as the paired t-test cannot be performed simultaneously on both groups [42]. Data from the experimental class were excluded when analyzing the control class, and vice versa. The t-test results for both the control and experimental classes will be presented in the following table. The mean values indicate the average scores of the pre-test and post-test for each group. The analysis shows that in both classes, the average post-test scores are higher than the pre-test scores. A more significant difference in mean scores was found in the experimental class, suggesting that students who participated in the experimental demonstration method experienced greater improvements in learning outcomes compared to the control class. The sample size for each variable is indicated by the N value. Table 3 below summarizes the t-test results for the data analyzed in this study.

Table 3. Descriptive analysis results for paired samples

Class		Mean	N	Standar Deviation	Standar Error Mean
Control class	Pre-test	60.91	25	10.81	
	Post-test	60.39	25	16.65	
Experimental class	Pre-test	61.69	30	11.08	
	Post-test	78.33	30	15.99	

Table 3 presents the descriptive statistics for the pre-test and post-test scores from the control and experimental classes. In the control class, the mean pre-test score was 52.67, with a standard deviation of 25.486 and a standard error of 6.580. After the intervention, the mean post-test score rose to 63.67, with a standard deviation of 16.952 and a standard error of 4.377, indicating an improvement in student performance. Meanwhile, in the experimental class, the mean pre-test score was 60.67, with a standard deviation of 20.777 and a standard error of 5.364. Following the experimental treatment, the mean post-test score significantly increased to 78.33, with a standard deviation of 15.999 and a standard error of 4.131. These findings demonstrate that both classes showed improvements in post-test scores compared to pre-test scores, with the experimental class displaying a more substantial increase. The number of participants (N) for each group remained consistent at 15 students, enabling a reliable comparison between the pre-test and post-test results.

The decision regarding the analysis results can be made by comparing the obtained t-statistic with the t-table value based on the determined degrees of freedom (df). The decision-making principle states that if the t-statistic is greater than the t-table value, H0 is rejected, meaning there is no significant difference, while Ha is accepted. Additionally, significance can be evaluated through the *p*-value found in the t-test result table (sig. (2-tailed) column). The basis for decision-making is that if the sig. (2-tailed) value is less than 0.05, H1 is accepted, indicating a significant difference between the initial and final variables, which signifies a significant effect of the treatment applied. Conversely, if the sig. (2-tailed) value is greater than 0.05, H0 is accepted, meaning there is no significant difference between the initial and final variables.

In this study, the significance value for the control class is 0.081, while for the experimental class, it is 0.000. For the control class, H0 is accepted, indicating that the treatment applied did not have a significant effect on the students' pre-test and post-test results. However, for the experimental class, the *p*-value is smaller than 0.05, meaning H1 is accepted, which indicates that the treatment applied, namely the experimental demonstration method, had a significant impact on the students' post-test results, with an average post-test score of 78.33 compared to the pre-test average of 60.67. Thus, it can be concluded that the experimental demonstration method is highly effective in improving students' understanding of the concept of adsorption, showing that this approach significantly enhances student learning outcomes.

D. Discussion

Based on the analysis conducted, it is evident that gamification in education has gained significant attention as an innovative method to boost student motivation and engagement. On one hand, gamification can enhance the learning experience by creating a fun and competitive atmosphere. Elements such as points, badges, and levels can motivate students to actively participate in learning and achieve predetermined goals [43, 44]. This approach can also increase student engagement by providing instant feedback and rewards for their achievements, reinforcing a sense of accomplishment and satisfaction in learning [45]. However, there are several limitations that need to be considered. One of these is the dependence on extrinsic motivation provided through rewards and competition. When students become overly reliant on external rewards, it can diminish their intrinsic motivation to learn, impacting long-term learning quality [46].

Additionally, gamification often requires access to technology, which may not be evenly distributed across all educational environments, leading to inequalities between students with and without access [47]. Moreover, excessive use of game-like elements can overwhelm students or trap them in routines that do not support deep understanding of concepts [48, 49]. These factors indicate that while gamification holds great potential for enhancing learning, its implementation must be approached carefully, taking into account the context and characteristics of students to achieve optimal and inclusive outcomes. Considering both sides of the issue, future studies may investigate on the effectiveness of gamification tailored to diverse student needs will offer deeper insights and practical benefits.

V. Conclusion

Recent observations indicate that theapplication of the experimental demonstration method in learning significantly influences student learning outcomes, particularly in understanding the concept of adsorption. Through the analysis of pre-test and post-test data in the experimental class, a higher average post-test score (78.33) was obtained compared to the average pre-test score (60.67), with a significance value (*p*-value) of 0.000, indicating a significant difference. In contrast, the results from the control class showed a significance value (*p*-value) of 0.081, which means there was no significant effect from the treatment applied. Therefore, this study concludes that the experimental demonstration method is effective in enhancing students' understanding of the material taught and can be recommended as one of the teaching methods to be used in education, especially in the context of teaching abstract science concepts. This research also opens opportunities for further studies on the effectiveness of other teaching methods in improving student learning outcomes across various fields of study.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Reni Rahmadani: Concept and drafting, helped with the data analysis, and did all the necessary revisions to comply with the standards of the journal. Tansa Trisna Astono Putri and Muhammad Dominique Mendoza: the gathering of data with the former, helped in the data analysis, and reviewed/edited the final version of the paper. Olnes Yosefa Hutajulu: Statistical analysis and Supervision. Elsa Sabrina: Drafting manuscript, Collecting Data, Statistical analysis. All authors approved the final version.

REFERENCES

[1] A. N. Saleem, N. M. Noori, and F. Ozdamli, "Gamification applications in e-learning: A literature review," *Tech Know Learn*, vol. 27, no. 1, pp. 139–159, Mar. 2022. doi: 10.1007/s10758-020-09487-x

[2] B. J. Blažič, "Changing the landscape of cybersecurity education in the EU: Will the new approach produce the required cybersecurity skills?" *Educ. Inf. Technol.*, vol. 27, no. 3, pp. 3011–3036, Apr. 2022. doi: 10.1007/s10639-021-10704-y

[3] H. Hidayat *et al.*, "Metacognitive awareness determination through technology: A problem-solving android gamification app," *Future*, vol. 14, no.8, pp. 1099–1108, Jan. 2024.

[4] E. V. Frolova, O. V. Rogach, and T. M. Ryabova, "Digitalization of education in modern scientific discourse: New trends and risks analysis," *European Journal of Contemporary Education*, vol. 9, no. 2, pp. 313–336, June 2020.

[5] B. J. Blažič and A. J. Blažič, "Cybersecurity skills among European high-school students: A new approach in the design of sustainable educational development in cybersecurity," *Sustainability*, vol. 14, no. 8, p. 4763, April 2022.

[6] G. B. Gudmundsdottir, H. H. Gassó, J. C. C. Rubio, and O. E. Hatlevik, "Student teachers' responsible use of ICT: Examining two samples in Spain and Norway," *Computers & Education*, vol. 152, 103877, July 2020.

[7] C. J. Hellín, F. Calles-Esteban, A. Valledor, J. Gómez, S. Otón-Tortosa, and A. Tayebi, "Enhancing student motivation and engagement through a gamified learning environment," *Sustainability*, vol. 15, no. 19, p. 14119, Sep. 2023.

[8] G. M. Chans and M. P. Castro, "Gamification as a strategy to increase motivation and engagement in higher education chemistry students," *Computers*, vol. 10, no. 10, p. 132, Oct. 2021.

[9] I. Semenets-Orlova, V. Teslenko, A. Dakal, V. Zadorozhnyi, O. Marusina, and A. Klochko, "Distance learning technologies and innovations in education for sustainable development," *Studies of Applied Economics*, vol. 39, no. 5, May 2021.

[10] J. Taylor-Jackson, J. McAlaney, J. L. Foster, A. Bello, A. Maurushat, and J. Dale, "Incorporating psychology into cyber security education: A pedagogical approach," in *Proc. Financial Cryptography and Data Security: FC 2020 International Workshops*, 2020, pp. 207–217. doi: 10.1007/978-3-030-54455-3_15

[11] M. T. Cespón and J. M. D. Lage, "Gamification, online learning and motivation: A quantitative and qualitative analysis in higher education," *Contemporary Educational Technology*, vol. 14, no. 4, p. ep381, July 2022.

[12] M. Anwar, T. Taali, H. Hidayat, and E. Sabrina, "Exploring trait thinking in predicting students' higher-order thinking skills (HOTS) using ANFIS: A study on electronics engineering education students," *TEM Journal*, vol. 13, no. 4, pp. 3103–3111, Nov. 2024.

[13] T. M. Tran, R. Beuran, and S. Hasegawa, "Gamification-based cybersecurity awareness course for self-regulated learning," *International Journal of Information and Education Technology*, vol. 13, no. 4, pp. 724–730, April 2023.

[14] L. Williams, E. Anthi, Y. Cherdantseva, and A. Javed, "Leveraging gamification and game-based learning in cybersecurity education: Engaging and inspiring non-cyber students," *Journal of The Colloquium for Information Systems Security Education*, vol. 11, no. 1, p. 8, Feb. 2024.

[15] M. Anwar, Y. Rahmawati, N. Yuniarti, H. Hidayat, and E. Sabrina, "Leveraging augmented reality to cultivate higher-order thinking skills and enhance students' academic performance," *International Journal of Information and Education Technology*, vol. 14, no. 10, pp. 1405–1413, Oct. 2024.

[16] M. Liesa-Orús, C. Latorre-Cosculluela, S. Vázquez-Toledo, and V. Sierra-Sánchez, "The technological challenge facing higher education professors: Perceptions of ICT tools for developing 21st century skills," *Sustainability*, vol. 12, no. 13, p. 5339, July 2020.

[17] A. Sinha, A. Adhikari, and A. K. Jha, "Innovational duality and sustainable development: Finding optima amidst socio-ecological policy trade-off in post-COVID-19 era," *Journal of Enterprise Information Management*, vol. 35, no. 1, pp. 295–320, Feb. 2022.

[18] E. L. Deci and R. M. Ryan, "The 'what' and 'why' of goal pursuits: human needs and the self-determination of behavior," *Psychological Inquiry*, vol. 11, no. 4, pp. 227–268, Oct. 2000. doi: 10.1207/S15327965PLI1104_01

[19] A. Rapp, F. Hopfgartner, J. Hamari, C. Linehan, and F. Cena, "Strengthening gamification studies: Current trends and future opportunities of gamification research," *International Journal of Human-Computer Studies*, vol. 127. pp. 1–6, July 2019.

[20] M. Czikszentmihalyi, *Flow: The Psychology of Optimal Experience*, New York: Harper & Row, 1990.

[21] A. N. Saleem, N. M. Noori, and F. Ozdamli, "Gamification applications in e-learning: A literature review," *Tech Know Learn*, vol. 27, no. 1, pp. 139–159, Mar. 2022. doi: 10.1007/s10758-020-09487-x

[22] S. H. Khahro and Y. Javed, "Key challenges in 21st century learning: A way forward towards sustainable higher educational institutions," *Sustainability*, vol. 14, no. 23, 16080, Dec. 2022.

[23] C. Van Diggele, C. Roberts, A. Burgess, and C. Mellis, "Interprofessional education: Tips for design and implementation," *BMC Med Educ*, vol. 20, no. S2, p. 455, Dec. 2020. doi: 10.1186/s12909-020-02286-z

[24] L. García-Pérez, M. García-Garnica, and E. M. Olmedo-Moreno, "Skills for a working future: How to bring about professional success from the educational setting," *Education Sciences*, vol. 11, no. 1, p. 27, Jan. 2021.

[25] M. Anwar, H. Hidayat, and E. Sabrina, "Exploring the use of genetic algorithms toolbox in engineering education: Did it provide an interesting learning experience for students?" *TEM Journal*, vol. 12, no. 3, pp. 1719–1724, Aug. 2023.

[26] M. Liu, R. Zhou, J. Dai, and X. Feng, "Analysis and practice of using modern information technology for classroom teaching mode reform," *Mobile Information Systems*, vol. 2022, no. 1, pp. 1–8, Aug. 2022. doi: 10.1155/2022/2565735

[27] A. A. Razak *et al.*, "Improving critical thinking skills in teaching through problem-based learning for students: A scoping review," *International Journal of Learning, Teaching and Educational Research*, vol. 21, no. 2, pp. 342–362, Feb. 2022.

[28] K. S. Gül and H. Ateş, "An examination of the effect of technology-based STEM education training in the framework of technology acceptance model," *Educ. Inf. Technol.*, vol. 28, no. 7, pp. 8761–8787, July 2023. doi: 10.1007/s10639-022-11539-x

[29] J.-Y. Fan, Y.-J. Tseng, L.-F. Chao, S.-L. Chen, and S.-W. Jane, "Learning outcomes of a flipped classroom teaching approach in an adult-health nursing course: A quasi-experimental study," *BMC Med. Educ.*, vol. 20, no. 1, p. 317, Dec. 2020. doi: 10.1186/s12909-020-02240-z

[30] C. Wang, J. He, Z. Jin, S. Pan, M. Lafkihi, and X. Kong, "The impact of gamification on teaching and learning Physical Internet: A quasi-experimental study," *Industrial Management & Data Systems*, vol. 122, no. 6, pp. 1499–1521, June 2022.

[31] Z. Luo, "Gamification for educational purposes: What are the factors contributing to varied effectiveness?" *Educ. Inf. Technol.*, vol. 27, no. 1, pp. 891–915, Jan. 2022. doi: 10.1007/s10639-021-10642-9

[32] K. P. Nuci, R. Tahir, A. I. Wang, and A. S. Imran, "Game-based digital quiz as a tool for improving students' engagement and learning in online lectures," *IEEE Access*, vol. 9, pp. 91220–91234, June 2021.

[33] A. C. Miola and H. A. Miot, "Comparing categorical variables in clinical and experimental studies," *Jornal Vascular Brasileiro*, vol. 21, e20210225, April 2022.

[34] N. S. Turhan, "Karl pearson's chi-square tests," *Educational Research and Reviews*, vol. 15, no. 9, pp. 575–580, Sep. 2020.

[35] A. Zeimbekakis, E. D. Schifano, and J. Yan, "On misuses of the kolmogorov–smirnov test for one-sample goodness-of-fit," *The American Statistician*, vol. 78, no. 4, pp. 481–487, Jun. 2024. doi: 10.1080/00031305.2024.2356095

[36] J. R. Lanzante, "Testing for differences between two distributions in the presence of serial correlation using the Kolmogorov–Smirnov and Kuiper's tests," vol. 41, no. 14, pp. 6314–6323, May 2021.

[37] I. Malá, V. Sládek, and D. Bílková, "Power comparisons of normality tests based on l-moments and classical tests," *Mathematics and Statistics*, vol. 9, no. 6, pp. 994–1003, Nov. 2021.

[38] E. M. Matore and A. Z. Khairani, "The pattern of skewness and kurtosis using mean score and logit in measuring Adversity Quotient (AQ) for normality testing," *International Journal of Future Generation Communication and Networking*, vol. 13, no. 1, pp. 688–702, Mar. 2020.

[39] J. Arnastauskaitė, T. Ruzgas, and M. Bražėnas, "An exhaustive power comparison of normality tests," *Mathematics*, vol. 9, no. 7, p. 788, April 2021.

[40] R. W. Emerson, "ANOVA assumptions," *Journal of Visual Impairment & Blindness*, vol. 116, no. 4, pp. 585–586, July 2022. doi: 10.1177/0145482X221124187

[41] K. Ujian, N. F. Abdullah, and N. Muda, "An overview of homogeneity of variance tests on various conditions based on type 1 error rate and power of a test," *Journal of Quality Measurement and Analysis JQMA*, vol. 18, no. 3, pp. 111–130, Jan. 2023.

[42] F. Fauzi, M. Erna, and R. Linda, "The effectiveness of collaborative learning throughtechniques on group investigation and think pair share students' critical thinking ability on chemical equilibrium material," *Journal of Educational Sciences*, vol. 5, no. 1, pp. 198–208, Jan. 2021.

[43] N. J. Thomas, R. Baral, and O. S. Crocco, "Gamification for HRD: Systematic review and future research directions," *Human Resource Development Review*, vol. 21, no. 2, pp. 198–224, June 2022. doi: 10.1177/15344843221074859

[44] W. Toh and D. Kirschner, "Developing social-emotional concepts for learning with video games," *Computers & Education*, vol. 194, 104708, Mar. 2023.

[45] Z. Luo, "Gamification for educational purposes: What are the factors contributing to varied effectiveness?" *Educ. Inf. Technol.*, vol. 27, no. 1, pp. 891–915, Jan. 2022. doi: 10.1007/s10639-021-10642-9

[46] J.-M. Campillo-Ferrer, P. Miralles-Martínez, and R. Sánchez-Ibáñez, "Gamification in higher education: Impact on student motivation and the acquisition of social and civic key competencies," *Sustainability*, vol. 12, no. 12, p. 4822, June 2020.

[47] L. S. Jen and S. H. M. Said, "Application of gamification in introduction to programming: A case study," *PEOPLE: International Journal of Social Sciences*, vol. 4, no. 3, pp. 845–864, Jan. 2019.

[48] S. Siripipatthanakul *et al.*, "Gamification and edutainment in 21st century learning," *Multidisciplinary Approaches to Research*, vol. 2, no. 1, pp. 210–219, Feb. 2023.

[49] J. Hamari, J. Koivisto, and H. Sarsa, "Does gamification work?—A literature review of empirical studies on gamification," in *Proc. 2014 47th Hawaii International Conf. on System Sciences,* 2014, pp. 3025–3034.