Interactive Learning Media Design: Quantum Learning-Based Digital Game for Electrical Engineering Education

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Abstract. This research aims to develop a Quantum Learning-based digital game as a learning media for electrical engineering education. Quantum Learning is an approach that integrates the psychological, emotional, and physical aspects of students to enhance the learning process. In this study, we designed and developed an interactive digital game focusing on electrical engineering subjects. The game was designed with consideration of Quantum Learning principles to motivate and engage students in the learning process. The research followed a development approach for learning media design, which involved phases such as needs analysis, design, development, implementation, and evaluation. Several electrical engineering classes students participated in the study to try and test the developed digital game. Data collection included students^ feedback on the game, effectiveness assessment, and a comparison of students^ learning outcomes before and after using the game. The results showed that the use of Quantum Learning-based digital games positively influenced students^ participation and understanding of electrical engineering concepts. This research contributes to the development of innovative and relevant learning media to improve the quality of electrical engineering education. In conclusion, implementing Quantum Learning in digital game development proved to be an effective strategy to enhance the electrical engineering learning process by increasing students^ motivation, participation, and understanding. This study has the potential to serve as a reference for learning media developers to optimize technology for achieving more effective and efficient learning outcomes in the field of electrical engineering.

Keywords: Quantum Learning, Digital game, Electrical engineering, Learning media, Student engagement.

1 Introduction

Education stands as a fundamental pillar in shaping the generations of the future. In this ever-evolving digital age, the landscape of education has undergone a significant paradigm shift. Conventional teaching methods are increasingly being supplanted by more interactive and technology-driven approaches. Education is no longer solely about information delivery; it is also about how that information can be better understood and applied by students [1].

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Electrical engineering education, like other fields of engineering, is not exempt from this transformation. To meet the demands of effective and engaging learning, we introduce an innovation: quantum learning-based digital games for electrical engineering education.

Electrical engineering education entails grasping concepts that are often intricate and abstract [2]. Students must master foundational principles to solve problems related to electrical circuits, programming, and cutting-edge technology. Educators worldwide have been searching for ways to make learning more engaging, interactive, and relevant for electrical engineering students. In this endeavor, the concept of quantum learning has garnered increasing interest.

Quantum learning principles, which emphasize active participation, critical thinking, and comprehensive understanding, have proven effective in transforming the traditional approach into a deeper and more meaningful learning experience [3]. In the context of electrical engineering education, integrating these principles into digital games enables students to actively explore complex concepts, develop critical thinking skills, and build a stronger grasp of the subject matter.

This paper will outline the stages of design, development, and implementation of quantum learning-based digital games for electrical engineering education. We will discuss how quantum learning principles are applied in the development of these games and share preliminary findings from their use in teaching. By doing so, we aim to provide valuable insights for education and research practitioners striving to enhance electrical engineering education through the use of cutting-edge technological innovations.

2. Literature Study

A literature review to support this research has been conducted, including quantum learning, digital game-based learning and, quantum learning in digital games.

2.1 Quantum Learning

Quantum learning, as an innovative approach in the field of education, aims to reshape how we perceive the process of teaching and learning. The core principles of quantum learning place learners in an active role, positioning them as independent seekers of knowledge rather than passive recipients of information. In this approach, learning is viewed as an ongoing journey of exploration, encouraging students to venture through the curriculum with questions, investigations, and experiments [4]. As part of these principles, research-based learning becomes a cornerstone, providing students with opportunities to develop critical and creative problem-solving skills.

Quantum learning also emphasizes the holistic experiences of students, acknowledging that learning is not just about the accumulation of facts but also about deeper understanding and the application of knowledge in real-life contexts [5]. In the context of electrical engineering education, this approach can help students not only comprehend the fundamental theories but also understand how these theories are applied in various technical situations. Furthermore, collaboration among students and the allowance for open-ended problem-solving are integral elements of quantum learning. When students learn together and engage in collaborative projects, they not only develop a deeper understanding but also valuable social and teamwork skills essential in the real world [6]. With quantum learning principles encompassing active exploration, holistic understanding, research-based learning, and collaboration, this approach provides a strong foundation for creating more dynamic and effective learning experiences in electrical engineering education.

2.2 Digital Game-Based Learning

Digital game-based learning has undergone rapid development and has become an increasingly essential approach in the field of education. Digital games provide a dynamic and interactive learning environment that captures students' attention and interest effectively [7]. Leveraging advanced digital technology, educational games can create simulations, challenges, and immersive scenarios that allow students to apply their theoretical knowledge to practical and relevant contexts.

Furthermore, the gamification elements often embedded within these games, such as rewards, achievements, and competition, stimulate students' motivation to actively participate in the learning process. With instant feedback mechanisms in games, students can observe the consequences of their decisions, refine strategies, and learn from their mistakes without the fear of real-world repercussions [8]. This fosters a safe learning environment for experimentation and skill development, which is a crucial component of effective learning. Thus, digital games are not only enjoyable but also powerful tools in promoting deep understanding and fostering creative problem-solving in education.

2.3 Quantum Learning in Digital Games

The incorporation of quantum learning principles into digital games creates a learning environment that inspires students to become more active and independent learners. In this context, the main principle of quantum learning emphasizes the development of deeper understanding through active exploration and collaborative problem-solving. Within digital games, these concepts are realized through various means that actively engage students. For instance, games may present complex challenges that require research-based problem-solving, enable players to explore virtual environments, or encourage collaboration with fellow players to achieve specific goals [9].

The application of quantum learning within digital games also encourages students to develop critical skills such as analytical thinking, initiative-taking, and effective communication. Through open-ended problem-solving and exploration within the game context, students can better grasp complex concepts, as they are not merely receiving information passively but actively seeking solutions and depth of understanding. By collaborating within the game, students also learn to work together with others, enhancing their social skills [10]. Therefore, the integration of quantum learning principles into digital games results in a deep, interactive learning experience that empowers students to take a more active role in their education.

In this way, quantum learning in digital games is not just about acquiring knowledge but also about the development of critical, creative thinking skills and collaborative abilities that are valuable for students in facing real-world challenges. This approach shifts students from being passive recipients of information to active agents of learning, potentially enhancing their comprehension of the subject matter and their readiness to tackle real-life situations [11].

3. Research Methodology

The Research and Development (R&D) methodology is an appropriate approach for developing an effective quantum learning-based digital game for electrical engineering education. This method involves a structured series of steps that enable researchers to design, develop, and test a game prototype before widespread implementation. Here are the nine steps within the R&D methodology [12]:

Needs Identification: The first step in R&D is to identify the needs for the digital game being developed. This involves identifying the primary learning objectives in the field of electrical engineering, as well as the challenges that the game needs to address.

Planning: In this phase, plan the entire development process, including the timeline, resources, and the required team. Create a development plan that encompasses the design phase, prototype development, testing, and implementation.

Needs Analysis: Conduct an in-depth analysis of educational needs and the target audience. Identify key learning components that need to be incorporated into the game to achieve the learning objectives.

Instructional Design: Create a detailed instructional design, including learning objectives, game structure, curriculum, and how the game will facilitate understanding of electrical engineering concepts.

***Prototype Development*:** Based on the instructional design, the development team will create a prototype of the digital game. This is an initial version of the game that includes some core components and learning concepts

Initial Testing: Conduct initial testing of the game prototype with a group of electrical engineering students. Gather feedback from them about aspects that need improvement, as well as the alignment of the game with the learning objectives.

Prototype Revision: Based on the results of initial testing, revise the game prototype. Address any issues found and enhance the quality of the game.

Advanced Testing: After revisions, perform advanced testing with a larger group to ensure that the game provides an effective learning experience. Measure students' progress and understanding in more detail.

Implementation: Once the game is deemed ready, implement it as an additional learning tool in electrical engineering courses. Monitor the game's usage and continue evaluation to ensure ongoing improvements.

By following these steps within the R&D methodology, it is expected that the quantum learning-based digital game developed will serve as an effective tool for enhancing learning in electrical engineering. This methodology allows for continuous improvement based on feedback and evaluation results, ensuring the long-term success of this project. The research steps with the R&D method are clearly illustrated in Fig.1.

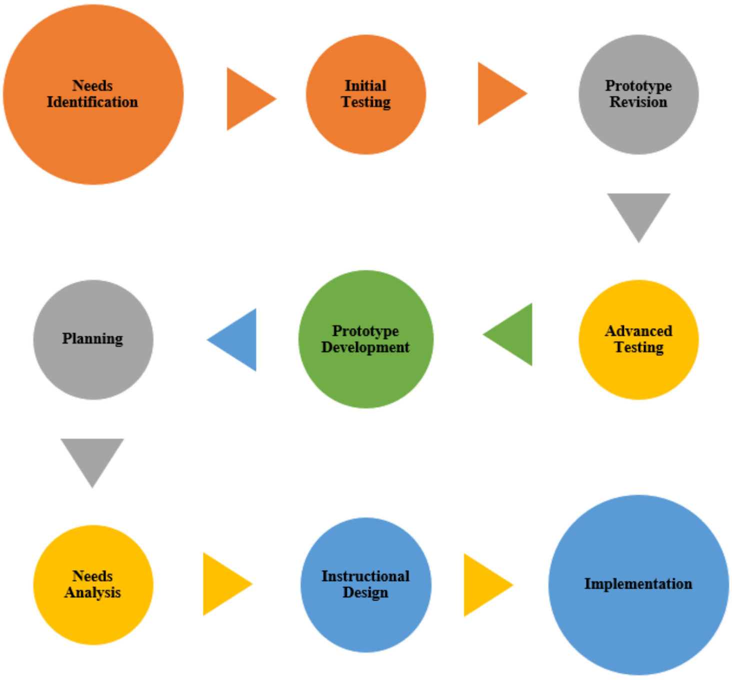

Fig. 1. The 9 steps of research using the R&D (Research and Development) method.

The data analysis phase in this research is crucial to measure the impact and effectiveness of the quantum learning-based digital game in electrical engineering education. Data analysis is conducted by utilizing quantitative data collected during the game's implementation. In this study, we employ two key parameters to gauge the effectiveness of the learning: test score improvement and knowledge retention rate. Test score improvement is measured by calculating the difference between post-test scores and pre-test scores, while knowledge retention rate is determined by calculating the percentage of knowledge retained by students within a specified time frame after the learning [13-14]. The formula to calculate test score improvement is as equation 1:

$$Test\ Score\ Improvement = Post\ Test\ Score - Pre\ Test\ Score \quad (1)$$

Where the Post-Test Score represents the score obtained by students after participating in the learning through the quantum learning-based digital game, and the Pre-Test Score is the score acquired before the learning. Test score improvement provides insights into the extent to which the game contributes to enhancing students' understanding of electrical engineering concepts. Furthermore, to compute the knowledge retention rate, we use the following formula:

$$Knowledge\ Retention\ rate = \frac{Retained\ Knowledge}{Initial\ Knowledge}\ x\ 100\% \quad (2)$$

Where Retained Knowledge represents the knowledge that students still hold within a specified time frame after the learning, and Initial Knowledge is the students' initial knowledge before the learning. The knowledge retention rate aids in evaluating how well the learning with the quantum learning-based digital game sustains students' understanding over the long term. The results of this data analysis will provide valuable insights into assessing the effectiveness of the digital game as a learning tool in electrical engineering education.

4. Result and Discussion

4.1 Research Product

The result of this development research is a digital game product that combines elements of role-playing games (RPG) with fundamental electrical knowledge. The digital game interface for quantum learning, as developed, is illustrated in Fig. 2.

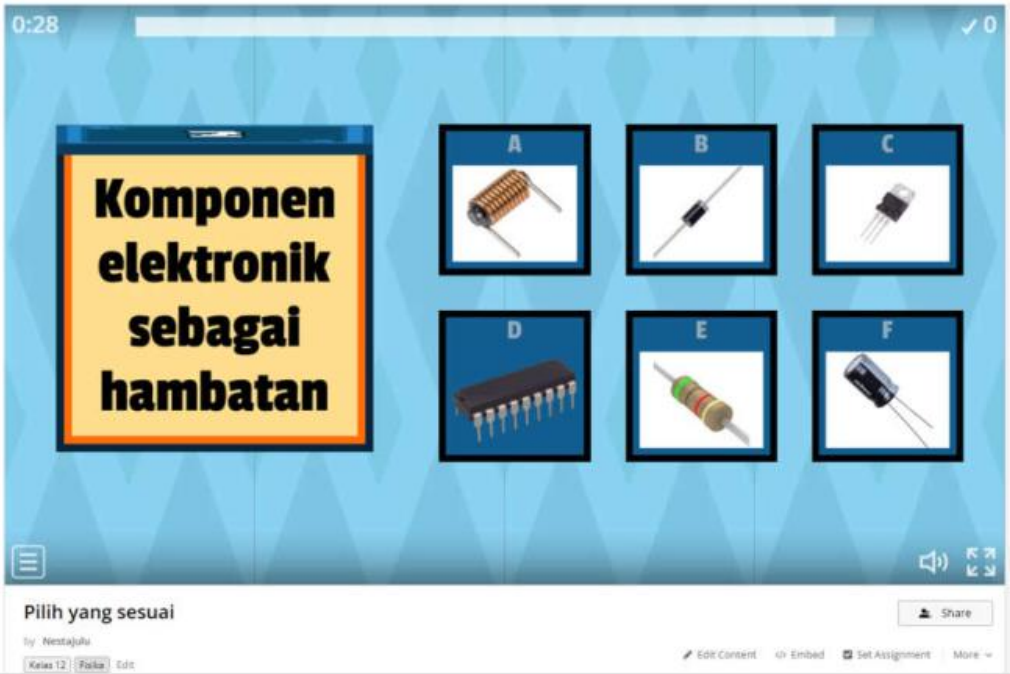

Fig. 2. The digital game interface for quantum-based learning.

The product developed in this research was then tested on students for the Basic Electronics course. The number of participants involved was 50 students, in accordance with the minimum sample requirement of at least 30 respondents [15]. The testing process for the students was conducted in three parts: pre-test, learning phase, and post-test. Subsequently, participants were given a one-week break. After this break, participants were asked to retake the test embedded within the game. This cycle is clearly illustrated in Fig. 3.

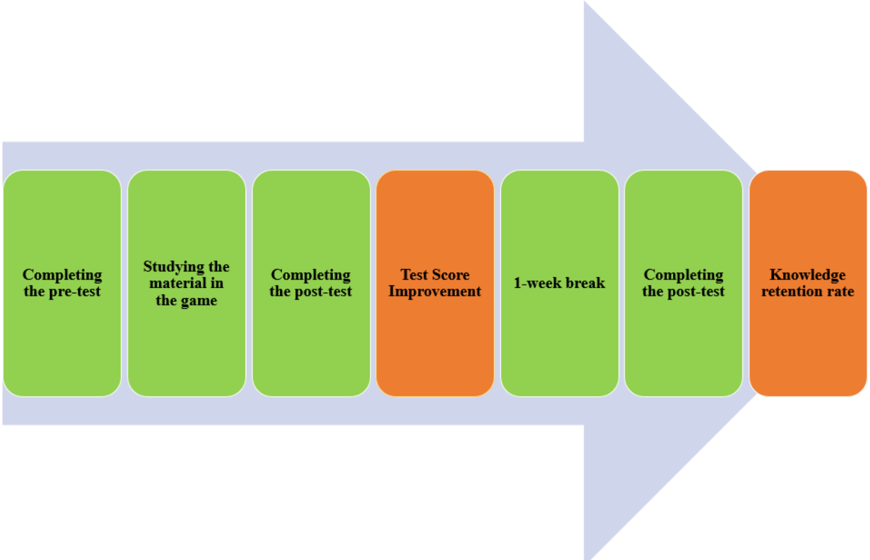

Fig. 3. The implementation of digital games for quantum-based learning involves 50 participants.

After the implementation phase of the quantum-based digital game for learning, participants were asked to complete a questionnaire to gauge their feedback on the developed digital game. The questionnaire consisted of 11 questions encompassing 9 dimensions that have been tested for their validation and reliability. The validation and reliability test results for all questionnaire items are presented in Table 1 and Table 2.

Table 1. Validation test result with corrected item-total correlation.

Question Items	Corrected item-total correlation	Question Items	Corrected item-total correlation
Engagement in Learning	**0.502**	Learning Motivation	**0.597**
Understanding of Subject Matter 1	**0.606**	Problem-Solving Skills	**0.704**
Understanding of Subject Matter 2	**0.602**	Interactive Experience	**0.694**
Critical Thinking 1	**0.467**	Satisfaction and Enjoyment	**0.435**
Critical Thinking 2	**0.689**	Self-Directed Learning Motivation	**0.747**
Collaboration	**0.324**		

Based on Table 2, it is evident that the computed r-count using the corrected item-total parameter ranges from the lowest value of 0.324 for question item number 6 to the highest value of 0.747 for question item number 11. Question items are considered "Valid" when the r-count greater than r-table [16]. The r table value used as a reference with a total of 50 participants with a significance level of 5% was set at 0.279. Based on this data, all question items have r-count greater than the critical r-table, indicating that all the validated question items are deemed as "Valid".

Table 2. Reliability test result.

Cronbach's Alpha	N of Item's
0.808	**11**

Reliability testing has also been conducted, and the results are presented in Table 2. Based on the data shown, the Cronbach's alpha value for all questionnaire items is 0.808. The reliability test results, according to statistical standards, can be considered "Reliable" if the Cronbach's alpha value is greater than 0.7 [16]. Looking at the data in Table 2, the questionnaire items are deemed "Reliable."

The assessment of the quantum-based digital learning game for the Basic Electronics course was conducted using a questionnaire administered to the participants. The assessment system utilized a Likert scale with 5 criteria, namely "Strongly Disagree," "Disagree," "Neutral," "Agree," and "Strongly Agree." The assigned values for each response were 1, 2, 3, 4, and 5, respectively. The results of the questionnaire assessment are presented in Table 3.

Table 3. Questionare result.

Question Items	Avarage Result	Question Items	Avarage Result
Engagement in Learning	**4**	Learning Motivation	**4**
Understanding of Subject Matter 1	**4**	Problem-Solving Skills	**4**
Understanding of Subject Matter 2	**4**	Interactive Experience	**3**
Critical Thinking 1	**4**	Satisfaction and Enjoyment	**4**
Critical Thinking 2	**4**	Self-Directed Learning Motivation	**3**
Collaboration	**4**		

Based on the questionnaire results presented in Table 3, the average responses from participants were "Agree" for 9 items and "Neutral" for 2 questions. This indicates that overall, the participants agree with the positive impact of the quantum learning-based digital game for learning.

4.2 Result Analysis

In this research, besides examining participants' responses to the digital game for quantum learning through a questionnaire, an analysis was also conducted on participants' test score improvement. The analysis was carried out following the guidelines of Equation 1. The results of the participants' pre-test and post-test can be seen in Fig. 4, and the test score improvement outcomes are presented in Table 4.

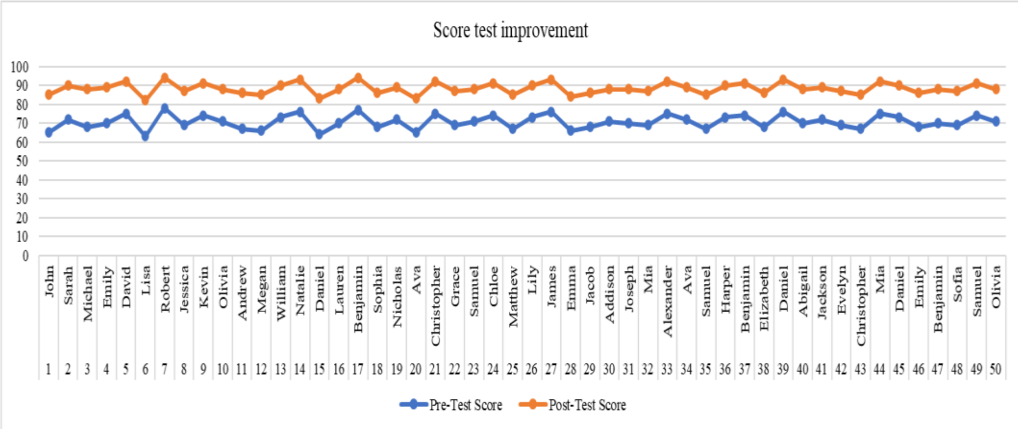

Fig. 4. Score test improvement.

Table 4. Average test score improvement result.

Average **pre-test** result	Average **post-test** result	Test Score Improvement
70.7	88.38	**17.68**

Fig. 4 show that there is an overall test score improvement for each participant after completing the digital game-based learning. The average test score improvement is found to be 17.68 points after participants have completed the learning, as shown in Table 4.

Furthermore, an analysis was conducted to assess the knowledge retention rate of participants after undergoing Basic Electronics learning with quantum-based digital game instruction. The overview of the knowledge retention rate results is presented in Figure 5, with the average knowledge retention rate values provided in Table 5.

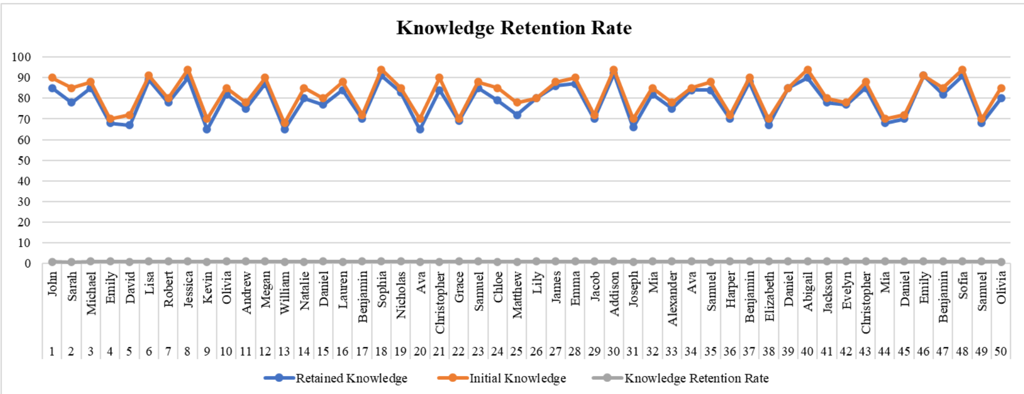

Fig. 5. Knowledge retention rate result

Table 4. Average knowledge retention rate result.

Average Initial Knowledge	Average Retention Knowledge	Average Knowledge Retention Result
82.00	78.98	**96.29 (%)**

Fig. 5 show that overall, participants were able to retain the knowledge acquired through quantum learning-based digital game-based learning. Based on Table 5, on average, participants were able to retain their knowledge at a rate of 96.29% with the learning interval provided over one week. These results are highly satisfactory.

5. Conclussion

In conclusion, this research highlights the significance of using quantum learning-based digital games in the context of electrical engineering education. The research results indicate that this approach can have a positive impact on student learning. Through the questionnaire responses, students expressed agreement that quantum learning-based digital games can enhance their deeper understanding of complex subject matter and increase their motivation to explore related topics more extensively. Furthermore, the game also demonstrates high knowledge retention value, indicating that students' mastery of the material improves, leading to the fulfillment of learning objectives.

Moreover, quantum learning-based digital games also encourage students to take initiative in self-directed learning beyond the classroom, suggesting the potential to be a valuable lifelong learning tool. Although these results are still in the testing phase and require further validation through broader testing and additional data analysis, this research provides intriguing insights into how the integration of quantum learning principles into digital games can stimulate more effective learning processes and motivation in electrical engineering education. Therefore, the development and implementation of quantum learning-based digital games have the potential to support innovation in future learning methods and enhance understanding of complex concepts in electrical engineering..

6. Acknowlegedment

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