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PAPER

Design and Development of Mobile Teaching Aids Using Go-Based Electronic Games for Teaching Digital Electronics in Higher Education

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ABSTRACT

The ongoing evolution of technology in education has highlighted the need for modernized instructional methods. This study explores the development of the Go Electronic game, designed to enhance teaching and learning in digital electronics through gamification. Students often face difficulties in understanding digital electronics, a complex subject that is difficult to learn through traditional teaching methods. This gap highlights the need for teaching aids that simplify concepts and maintain student focus through interactive learning approaches. Using the Waterfall model, a systematic development methodology that progresses through sequential phases: requirements analysis, system design, implementation, integration, testing, and maintenance. This approach ensures that each stage is thoroughly completed before moving to the next, allowing for a structured and efficient development process. Go Electronic was developed to address the confusion often faced by university students in this subject area. The research focuses on the integration of new media resources to make the learning process more interactive and engaging. Data collected from interviews with educators at Universiti Pendidikan Sultan Idris (UPSI) confirmed the tool's effectiveness, emphasizing its potential to improve student focus and engagement. The research findings indicate that the Go Electronic game, developed using this model, effectively enhances student engagement and focus on digital electronics topics. Feedback from educators highlights that the gamified approach not only captures student interest but also supports a more interactive and productive learning experience. The study suggests that expanding the game's question bank could further improve students' comprehension, thus advancing the integration of gamification in higher education course delivery.

KEYWORDS

teaching aids, digital electronics, electronic technology subjects, scratch games, university students

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1 INTRODUCTION

The subject of electronic engineering is one of the fields of technological engineering from the branch of electrical engineering. Under the branch of electronic engineering, it is divided into several sub-branches, such as analog electronics, digital electronics, consumer electronics, and power electronics. Electronic engineering involves the implementation of applications, principles, and related algorithm development. With this electronic engineering, society can use the latest medium that is able to give and receive information faster. Humans can be called homo technologicus (human-technological), which means humans who have the skills or ability to continue to develop technology to adapt, facilitate activities in life, and maintain their lives [1]. The development of the subject of electronic engineering parallels the progress of technological changes that occur, especially in educational institutions. In this global era, the challenge of IR 4.0 in education is through industrial automation and the creation of digitization literature that plays an important role in technology in influencing how educational curriculum is developed and implemented [2, 3].

The subject of electronic engineering helps to produce students who have knowledge and skills in the field of electronics that are geared towards industrial electronic systems and electronic audio-visual technology. The skills that students need to have been information technology skills, high-level thinking skills, teamwork skills, communication skills, and time management skills in facing the challenges of Industrial Revolution 4.0 [4]. Electronic engineering subjects can also produce designs in the production, maintenance, manufacturing, and equipment sectors related to electronic systems used in industry. This subject has been studied a little, starting from high school until more deeply in the university realm. The subject of electronic engineering involves observing a very broad and important field of engineering.

Electronic engineering is the use of electrical devices that operate with the flow of electrons or any electrically charged particles. Electronic engineering is different from electrical and mechanical engineering, which involves generation, distribution, switching, and storage [5]. This subject really needs computing skills and problem solving for a problem based on learning programming. In addition, this engineering uses all new knowledge or discoveries that have been produced by scientists to create various inventions that help people's daily lives [6]. In this subject too, students need to know about components, power, programming, and circuits to do practical projects. One of the technical competencies required in smart technology work is the ability to solve problems in identifying circuit faults, mechanical components, electronic detection, and signal processing [7]. Both skills require knowledge and skills from various other subfields such as electronic skills and programming.

Teaching materials and learning methods in universities still maintain conventional methods. The learning process cannot be encouraged if teachers are still tied to conventional teaching methods; then the failure of teachers to introduce learning methods that are in line with current trends leads to students' setbacks in academic performance [8]. The problem of university students when studying the topic of digital electronics is that students quickly feel bored and confused about the topic, so they pay less attention during the learning process. Reading such reading material causes students to focus less and feel sleepy while getting information [9]. With that, improvements need to be made in more enjoyable and safer learning methods using interactive game methods and software related to electricity and electronics produced as one of the teaching aids for lecturers [10]. Online learning is

learning that uses the internet and some other important technologies to develop for educational purposes, teaching delivery, and program management [11]. This method is also expected to attract students' interest because applications with gamification elements can help students be more active in learning sessions and avoid emphasizing their mental state. Multimedia-based teaching and learning can attract students' interest and focus and further impact students' motivation to deepen their knowledge [12].

Next, with a combination of learning the concept of gamification about digital electronics can help students in various aspects. Previous research states that game development is now aimed at the digital educational game industry [13]. Therefore, with the existence of this Go Electronic application, it can help students improve themselves in learning so that students can have a brighter life in the future. Teaching aids refer to any resources or tools used by teachers or educators to improve the quality and effectiveness of their teaching. These materials are designed to help clarify, strengthen, and deepen students' understanding of a topic or concept being taught. 21st-century learning allows teachers to be more innovative in creating an effective PDP process and making learning more interesting [14]. The use of teaching aids is very important in education because it can make the learning process more interesting, interactive, and effective.

The use of effective teaching aids can improve understanding, motivate, and support the achievement of better learning outcomes. This is an important aspect of the modern teaching approach, which recognizes the need for more successful learning methods. The development of education in the age of information and communication technology requires teachers to be creative and innovative in their efforts to educate students [15].

The type of teaching aid is a game concept. Game education has also been known as 'game-based learning,' which is an approach in education using games to strengthen educators' teaching. Digital learning is important nowadays because without it, students will be far behind [16, 17]. This approach integrates the design principles of a game into the education sector to create a new learning experience and provide a positive impact.

Gamification education, or gamification in education, refers to the use of game mechanisms and elements in the context of education to increase student motivation and engagement during the learning process [18]. The teaching and learning cycle that uses technology and takes the form of interactive teaching and learning is more interesting to students because interactive learning is creative, innovative, and interesting and can even be accessed anywhere [19]. Gamification is not about turning education into a game but rather about using game design principles to create a more engaging and motivating learning experience for university students [20]. The gamification approach in education can help students enrich their learning experience by stimulating various skills such as high-level thinking skills (HLD), 21st-century skills, and problem-solving skills [21].

Educational games can be used to increase interest and motivation in learning and provide interesting new experiences to students in learning activities [22]. Computational thinking can be interpreted as a human process in formulating and solving a problem and finding a suitable and practical solution to the problem faced effectively and efficiently [23]. When students use this Go Electronic application, they will learn to solve problems with the available options as if they were the same as the quiz questions given that also have answer options.

Cognitivism theory is one of the main theories in the field of education and learning psychology. This theory focuses on mental processes and how those processes

affect learning. This cognitivism was chosen by the researcher because it is closely related to behaviorism theory, which emphasizes observable behavior and ignores mental processes. Through the theory of cognitivism, a child's behavior can be evaluated from acceptance and understanding, not from visible behavior alone [24]. Based on the theory of cognitivism, the teacher acts as a conveyer of information and ensures that students have existing knowledge. Therefore, all planning is done according to the sequence of activities so that the learning objectives are achieved. The Waterfall model is a methodology used in software development and one of the oldest models. This model is known for its linear approach where each phase of the development process should be completed completely before the next phase begins. The Waterfall model has several advantages, such as being easy to understand and implement, as well as having a clear structure. In the Waterfall model, the analysis stage known as requirements analysis is an important early stage in software development. At this stage, the primary objective is to collect, understand and document what the system expects. The design stage is an important step that follows the requirements analysis. At this stage, the focus is on the form of solution that meets the requirements that have been set. The design level is divided into two, namely conceptual design (high design) and detailed design (low level design). The development or implementation stage is the stage where the design that has been made in the previous stage is converted into real source code, producing functional software. This step is the concept and prototype embodied in a concrete solution.

Next, the validation stage, also known as the testing stage, is an important step after the development or implementation stage. At this stage, the software developed will be tested carefully to ensure that it meets all the specified requirements to be free of any defects. This verification aims to verify the quality of the software and guarantee its reliability before it is released into production. The maintenance stage is the final stage of the software development cycle. At this stage, the software will be released and actively implemented, and the development team is responsible for ensuring that it continues to function properly; in addition, it works to fix bugs that appear after launch, implement updates and improvements and ensure long-term stability in terms of security.

Electronic engineering refers to the study of the design and production of electronic circuits that function as information transmission. The development of electronic circuits involves the use of various components such as capacitors, diodes, transistors, resistors and inductors. Electronic engineering covers everything from identifying problems to solving problems in physical form and programming. In engineering there is a topic on digital electronics that uses digital signals consisting of binary codes that are (0 and 1). Digital electronics also have basic logic gates and combinational logic gates. In terms of calculation methods based on Boolean tables. Digital circuit design has its own programming as in computer programming. Digital electronics involves the use of digital component devices such as ICs (integrated circuits), transistors, resistors, capacitors and inductors. ICs can contain various types of logic circuits or complex logic circuits.

The integration of gamification and innovative teaching methods into electronic engineering education addresses the challenges of traditional pedagogies. By enhancing engagement and motivation, these methods support the development of essential skills and prepare students for future technological advancements. Electronic engineering remains a dynamic and evolving field, underscoring the need for continuous adaptation and improvement in educational practices.

Recent studies support the use of gamification and digital tools to bridge these gaps in student understanding. Research by Mazlan et al. [25] shows that educational

games in STEM subjects can significantly enhance motivation and cognitive engagement. Another study highlights that gamified educational media, such as Scratch, improves focus and retention in subjects involving problem-solving and logic, aligning well with the needs in digital electronics education [26]. These findings underline the potential for tools such as Go Electronic, developed in this study, to transform learning experiences by making abstract concepts more accessible through interactive, game-based methodologies.

2 METHODS

2.1 Research design

The study utilized a mixed-method approach combining qualitative and quantitative methods. This allows for an in-depth understanding to investigate the validity of Digital Electronic Teaching Aids (BBM) for enhancing students' understanding of symbols and the calculation of combinations between basic logic gates (qualitative) and a broader evaluation of the application's effectiveness (quantitative). A qualitative phase was conducted to develop and refine the Go Electronic game based on expert insights, followed by a quantitative phase to evaluate its impact on student learning and engagement.

The Waterfall model is used in this study because it is a design model that is often the basis for other design models. In general, the Waterfall model consists of analysis, design, implementation, testing, and maintenance phases. One of the advantages of this model is that it contains five basic phases to teaching design. These phases have their own purpose, which can be referred to in organizing work steps during the process of developing teaching aid materials. This model is known as a linear approach where each phase of the development process must be completed completely before the next phase begins.

2.2 Participants

The research was conducted at a public university in the state of Perak Darul Ridzuan. Three experts with diverse work experiences were selected as participants. Their expertise was considered important to assess the validity of the teaching aids. They were interviewed (lecturers or instructional designers specializing in digital electronics) to validate and provide feedback on the educational design of the game. The backgrounds and experiences of these respondents varied, providing a comprehensive perspective on the subject matter, as outlined in Table 1.

Table 1. Respondent profile

Respondent	Gender (F/M)	Background/Job Position and Field	Work Experience
Respondent 1	Female	Technology Education Lecturer	17 years
Respondent 2	Male	Technology Education Lecturer	13 years
Respondent 3	Female	Technology Education Lecturer	15 years

In addition, 20 students studying electrical and electronic engineering as a subject at the Faculty of Technical and Vocational at Sultan Idris Education University

were involved through pre- and post-tests to evaluate the effectiveness of using the application.

2.3 Research instruments

The primary research instrument was a semi-structured interview protocol developed by the researcher. This protocol was designed to elicit detailed responses from the experts regarding their views on the effectiveness of the digital electronic teaching aids. The interviews were conducted face-to-face and recorded using a voice recorder on a mobile phone to ensure accurate data capture and facilitate repeated review. The research design involved conducting semi-structured interviews with three experts to gain insights into the effectiveness and relevance of the teaching aids. This method was chosen to explore the depth of knowledge and experience of the respondents regarding the design and application of educational media content. Meanwhile, pre- and post-test assessments with students using the Go Electronic game could measure improvements in understanding and engagement.

2.4 Data analysis

The data analysis involved transcribing and coding the recorded interview sessions. Content analysis was employed to systematically analyze the interview data, enabling the researcher to identify key themes and insights relevant to the effectiveness of the teaching aids. This approach allowed for an in-depth understanding of the experts' perspectives and the validation of digital electronic teaching aids.

Statistical methods (paired t-test) were conducted to compare pre- and post-test scores and determine the impact of the game on learning outcomes. Descriptive statistics can summarize student survey responses on engagement and satisfaction.

2.5 Ethical considerations

Ethical considerations were upheld throughout the research process. Participants were informed about the purpose of the study and provided consent before participating in the interviews. The use of voice recordings was approved by the participants, and all recorded data was kept confidential. The researcher ensured that the data analysis process was conducted with integrity, maintaining the confidentiality and anonymity of the respondents.

3 RESULTS AND DISCUSSION

3.1 Prototype

This study was conducted to develop an online gaming application for the topic of Digital Electronics, namely the Go Electronic Application. The development and design of the application prototype in this study is based on several phases found in the Waterfall teaching design. The Waterfall Model is an abbreviation of Analysis, Design, Implementation, Testing, and Maintenance. Based on the Waterfall Model, many researchers have developed Go Electronic applications (Refer to Table 2).

Table 2. Prototype model

Researcher	Research Topic	Application
Yusuf [11]	Mobile-Based Mangrove Love Application Design in Kota Pari Village Using the Waterfall Method	Mangrove Love
Hidayah [12]	Development of Student Violation Monitoring Application at SMA Negeri 1 Madiun	Monitoring
Haba & Talakua [13]	Gamification Of Learning Scratch in Elementary School	Scratch
Hasanah & Yahfizham [14]	Use Scratch for Teaching Second Languages	Scratch

3.2 Analysis phase

The analysis phase is the first phase of the Waterfall model. With that, the production of this application has been developed to overcome the problems faced by students who are less interested in learning using conventional teaching methods in addition to being able to provide positive stimulation to students while in PdPc. The target user is suitable for all students studying the subject of Digital Electronics. This Scratch game concept game application is titled Go Electroni; it is suitable for all levels of university students. This learning standard is also suitable based on the proforma for the Electronic Technology course. This Go Electronic application is open source and hence it can be accessed on any type of device, any time.

3.3 Design phase

In the process of this design phase, the development of teaching aids needs to go through several research procedures involving related works. This procedure begins with the researcher looking for information about the Scratch application and learning about block coding from online sources. Next, the researcher will start synthesizing the idea in the form of a sketch and make a choice of the type of game that they want to use in developing the product.

Scratch can be used to create interactive stories, animations, quizzes, games, simulations, and more, depending on the creativity of the developer. Scratch makes it easy for developers to program into learning media without having to learn a complicated programming language for the public. The developed Scratch application is very good for use in the learning process of students [27]. The development of teaching aids that are produced must meet the needs of the lesson or attract the interest of students focused on interactive learning that makes students enthusiastic to learn it. Scratch has several features that make it an effective learning tool [28]. This phase also includes an overall view of design, learning theory, structure, and learning objectives. There are three aspects in design involved in the development of this mobile application.

Module design. The main design involved in the development of this Go Electronic application based on various types of devices is the module design. Figure 1 shows the design of the modules involved in the Go Electronic application development process. This Go Electronic application has several options that have been set.

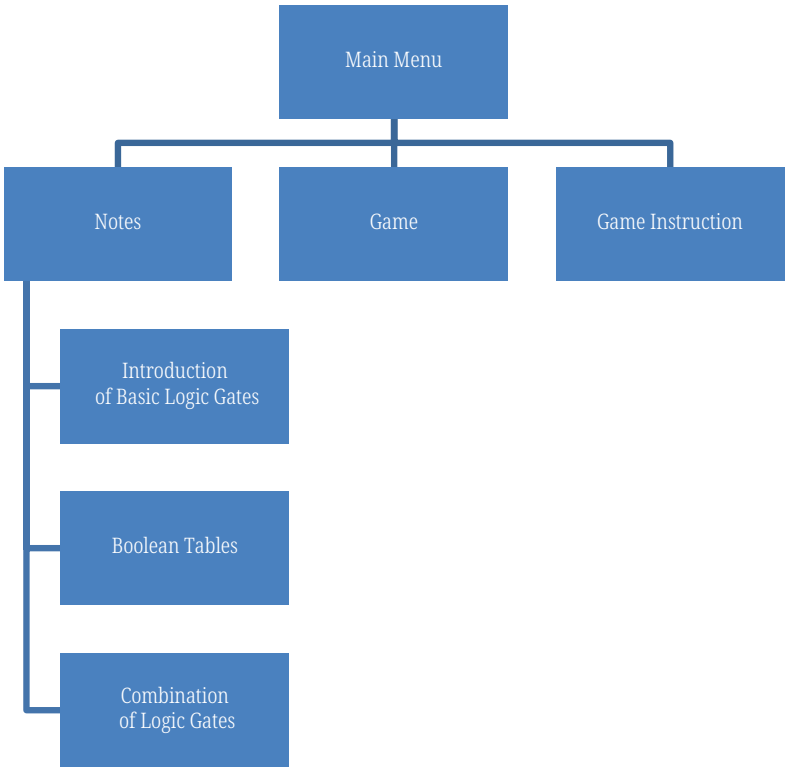

Fig. 1. Go Electronic application module design

This Go Electronic application consists of three main items, namely Notes, Games, and Game Instructions. This item will give different delivery. For the first item, which is a note that provides information on three subtopics, namely the introduction of basic logic gates, Boolean tables, and combinations of logic gates. In the note item, there are picture elements that can provide an understanding that improves the user's knowledge. In addition, the game section will provide entertainment in terms of the game, namely 'Catch the ball,' then continue with the level 1 quiz, which has two questions. After level one is over, level 2 and level 3 follow. Each level has two types of questions. The questions provided have been built based on the content found in the notes. Students are required to answer the question as a reinforcement activity after playing the provided game. In the game instruction section, the steps of the game are explained so that it is easy for users to use the application. Table 3 shows the four main sections and a summary of information for each section.

Table 3. Main sections and a summary of information

Section	Summary Information
Notes	This section describes the introduction of basic logic gates, Boolean tables and combinational logic gates
Game	This part of the game can be answered after completing the 'Catch the ball' game. After the game, the level 1 quiz will come out which has the next 2 questions to the other level which is level 2 and 3.
Game Instructions	This section also explains the steps of how the game is run so that users can use the application properly

Design of multimedia elements. Multimedia design is a technique in integrating various media such as text, graphics, audio, images, and others. The use and addition of multimedia elements in this application is intended to produce effective information delivery through the use of interesting, computerized technology. There are five multimedia elements included in the Go Electronic application, namely typography, text, image, audio, and graphics. The design of the typographical multimedia elements used involves the selection of typefaces and the type of writing colors used. Because this application is developed for the purpose of learning and game concepts, the text design, which is the type of font chosen, should be clear and bright for the presentation of information that is clear and easy for users to understand. The types of fonts chosen are "Sans Serif" and "Handwriting." Both writings are suitable for use because they have game elements. Figure 2 shows the type of sans-serif font used.

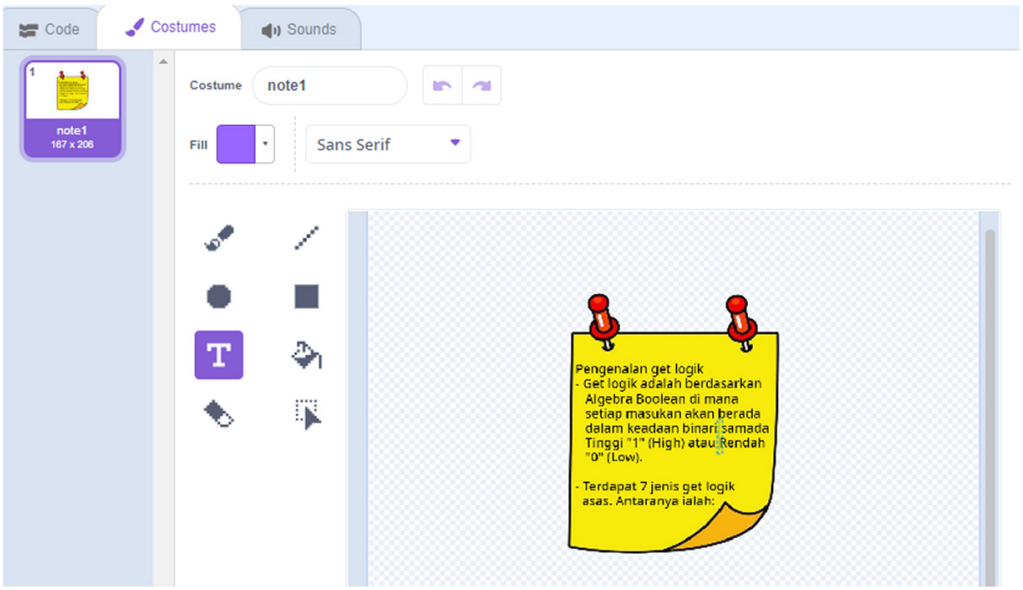

Fig. 2. Use of sans serif font

The use of icons in the Go Electronic application, where icons are used to symbolize the function of the symbol or picture itself. The main purpose of the icons downloaded into the Go Electronic application is to make it easier to use the application to access information faster and easier.

Interface design. The design of the interface found in e-learning plays a role in the organization of each part in order to be an organized application. Having an attractive interface design in terms of background and so on can increase students' interest in involvement in the use of the Go Electronic application.

In the interface design, the design of multimedia elements is also included, as shown in Figure 3. Among them is the use of harmonious colors that can be linked to the concept of the game and also the typography in the design part. In addition, the layout is designed neatly and organized, the navigation is also planned carefully so that the elements provided can work well to ensure maximum use can be benefited by users, namely among university students. Most studies say that shown images facilitate individual memory [29]. Application interface design based on the storyboard that has been designed for the Go Electronic application, is illustrated in Figure 3.

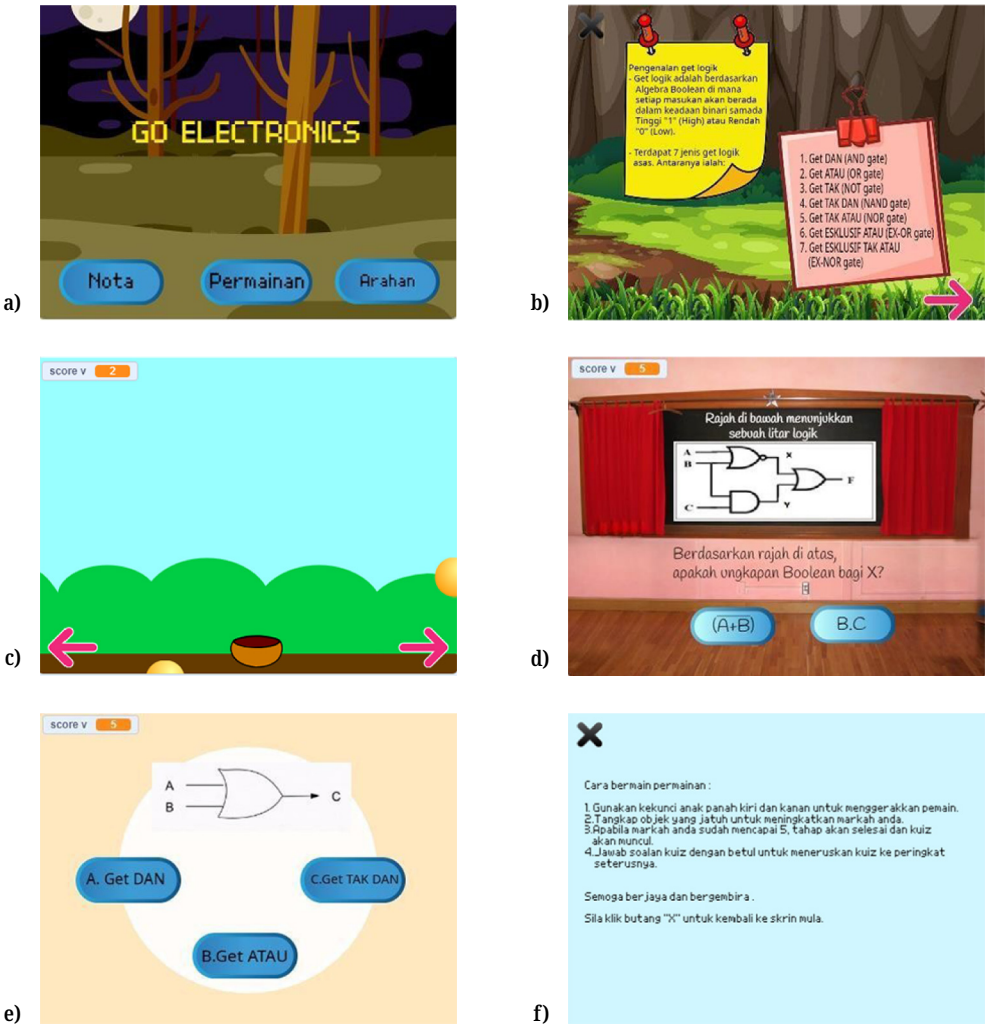

Fig. 3. (a) Go Electronic interface display, (b) Notes interface display, (c) Game interface display, (d) Easy level question interface display, (e) Difficult level question interface display, and (f) Intermediate display game instructions page

3.4 Implementation phase

In this development phase, all preliminary planning, such as storyboards, game construction, and interface design made in the design phase, will be implemented well. With that, the previous phases will also be changed according to the needs of the software used. This Go Electronic application is developed using the Scratch application, which is an open-source type because it can be accessed anywhere and anytime.

The design that has been made will become a real product by producing software that works as described before. This step has also included some coding according to the levels that have been arranged on the teaching aids. The use of multimedia presentations results in learning that gets a higher level of satisfaction with the type of teaching strategies provided that make them enjoy the subject more [30]. Figure 4 shows an example of coding for one quiz question element item after the game is played. The type of programming used in this Go Electronic application is the block programming type.

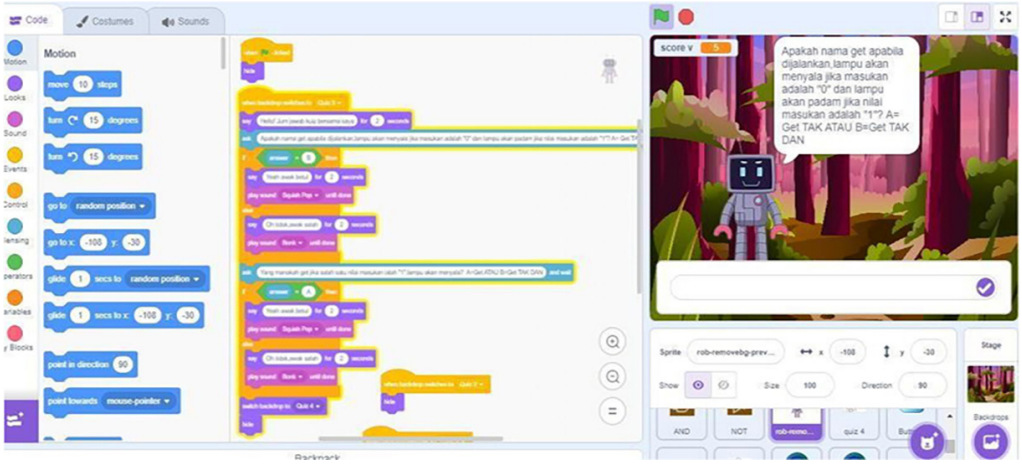

Fig. 4. An example of block coding on the item part of the quiz question element

3.5 Testing phase

The testing phase aims to provide an opportunity for the Scratch software that has been developed to have several common items to be complete as teaching aids. The software developed will also be thoroughly tested to ensure that all students' needs can be met. The Go Electronic teaching aids that have been developed will identify errors during the BBM development process through semi-structured interviews with three experts who have a background in engineering.

By testing the Go Electronic application with five experts, we will evaluate the effectiveness or need of the application in terms of elements of notes, games, and quizzes suitable and effective for university students. With this, researchers can ensure that users can be enthusiastic and better understand the topic of digital electronics.

3.6 Maintenance phase

This maintenance phase will be done by the researcher by identifying bugs or any damage in the application. If there is damage or a bug detected, the researcher will fix it properly so that the application can work continuously. Improvements can also be implemented in order to guarantee the stability of the use of teaching aids in the long term. With this, students can learn while enjoying fun through games. Students will be more active and conductive in the future.

3.7 Study instrument

This study was conducted using a mixed-method approach. Qualitative data were collected using semi-structured interviews, namely by asking questions related to digital electronics content and learning interface design. The qualitative method was chosen as the research method in learning that will be carried out using the interview method to obtain more accurate data. With that, the research instrument used by the researcher in this study was to create interview questions that would be asked to three selected respondents. This method aims to obtain all information about the usefulness of the Go Electronic application among students and lecturers in a comprehensive and enjoyable manner. While quantitative data is carried out through pre-tests and post-tests to measure the impact before and after using the application.

3.8 Qualitative result

Contents of the Go Electronic application. In general, from the results of the research, the researcher found that all the respondents agreed that this Go Electronic Application. The following will be explained in relation to applications related to BBM development and BBM functionality:

- Development of teaching aids
- Functionality of teaching aids

In terms of the development phase of teaching aids implemented in Go Electronic, they are used appropriately because they are easy to understand. This is because the sentences used are simple and limit conciseness. According to informant 2, the development of teaching aids based on the Go Electronic game makes a difference to learning. This interactive BBM development can help students understand the topic quickly and can raise their spirits.

> *"This BBM can help students because before there was a lot of ABM development that can be felt physically, but this is in a device, so it makes things easier for others." – (R1)*
>
> *"The development of this BBM is to meet the needs of students to understand the topic of digital electronics. Teaching aids can be used to attract students to enthusiastically study subjects related to skills." – (R3)*

In terms of the usability of teaching aids, it has also been agreed to be developed and applied in lectures. This is because, with the use of the Go Electronic application, users can understand the knowledge of digital electronics. In this phase, the researcher also learns to correct mistakes repeatedly so that he can produce the Go Electronic application well and perfectly.

> *"Having gamification in learning will make it easier for students to identify and understand about digital electronics." – (R1)*
>
> *"The development of this BBM is very helpful for students to understand more deeply related to the topic of digital electronics, the developed BBM works smoothly and is well used in the Pdp process in lectures." – (R2)*
>
> *"The preparation of questions from beginning to end in an orderly manner and students will understand easily when playing it." – (R3)*

Go Electronic application design elements. Findings through interviews found that image elements such as pictures, sounds, backgrounds, and icons included are interesting because the use of these elements can attract users' interest when using the Go Electronic application.

> *"The selection of colors on each interface is appropriate and can attract students to use it." – (R1)*
>
> *"Some students have to be targeted so they will study first before playing this game." – (R2)*
>
> *"Digital electronics is a very interesting topic if you produce a BBM with the addition of elements that have their own functions." – (R3)*

Next, the findings of the interview also found that in terms of organizing the elements of the interface, it is very important to ensure that the Go Electronic

application is in order to ensure that the process of transferring ideas from the initial sketch to the actual application can be carried out smoothly without any interruptions or errors.

Suggested application improvements. Some ideas or suggestions were given by all respondents. It included the following:

- The background color so that the questions stated in the quiz can be seen clearly and easily read.
- The design produced is in an application that can be opened with a link or by scanning a QR code.
- Increasing the number of questions to add more interesting Go Electronic games so that it can make students complacent when playing with it.

3.9 Quantitative result

Table 4 shows the pre- and post-test data for 20 students in a study assessing the effectiveness of the Go Electronic game in improving understanding in digital electronics. The data table includes hypothetical scores from tests taken before and after using the game. Scores are out of 100, representing students' knowledge or understanding of digital electronics concepts.

Table 4. Pre- and post-test analysis

Student ID	Pre-Test Score	Post-Test Score	Percentage (%)
S1	60	78	30
S2	55	72	31
S3	62	80	29
S4	47	70	49
S5	50	68	36
S6	58	75	29
S7	65	82	26
S8	52	69	33
S9	61	78	28
S10	57	76	33
S11	49	71	45
S12	63	81	29
S13	55	74	35
S14	48	69	44
S15	59	77	31
S16	53	72	36
S17	60	79	32
S18	56	73	30
S19	50	70	40
S20	62	80	29

Table 5 shows the pre-test mean score is 56.1, with a standard deviation of 5.87, while the post-test mean score is 74.7 with a standard deviation of 4.72. The smaller standard deviation in the post-test indicates a reduction in score variability, suggesting more consistent performance across students after the intervention.

Table 5. Descriptive statistic

	Mean	N	Std. Deviation	Std. Error Mean
Pair 1 Pre	56.10	20	5.87	1.31
Post	74.70	20	4.72	1.06

The mean difference between the pre- and post-test scores is –18.6, with a standard error of 0.61. This confidence interval (–19.89 to –17.31) does not include zero, supporting that the mean improvement is statistically significant. The t-statistic of –48.11 and a 2-tailed significance value (p-value) of 0.000 confirm that the improvement in scores is statistically significant at $p < 0.05$ (refer to Table 6). It can be concluded that analysis indicates a highly significant increase in understanding, further affirming the positive impact of the Go Electronic game on students' learning outcomes in digital electronics.

Table 6. Paired samples test

	Paired Differences					t	df	Sig. (2-Tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair Pre-post	–18.60	2.74	0.61	–19.89	–17.31	–48.11	19	0.000

Based on the results and discussion above, this study's findings align with other research supporting gamification as an effective tool for enhancing student engagement and understanding in technical subjects. For instance, studies such as Hidayah [13] and Kurniawan and Risnani [22] have demonstrated that gamified educational tools significantly boost motivation and comprehension in STEM subjects by incorporating interactive elements that cater to diverse learning needs. Similarly, applications developed using Scratch for educational games, as noted by Mazlan et al. [25], have shown promising results in making complex concepts more accessible, which parallels the positive impact observed with the Go Electronic application.

The researcher also found that there are several advantages and disadvantages that have been identified through several recommendations that have been given to ensure that the Go Electronic application can be used properly. Student motivation and involvement are important elements to encourage student behavior in the Learning and Facilitation (PDPc) session to complete a task [31]. Among the advantages of the application produced is that the note information in the Go Electronic application is authentic and reliable. This is because the contents of the notes are obtained through notes from lecturers at UPSI in the field of electronic technology engineering. In accordance with the era's damping, the presence of simple and matching notes repeatedly in the game will help students to be more interested in learning [32]. Forming a positive attitude towards learning, a more interesting and authentic language learning environment, and improving student motivation and performance in class [33].

When students start to enjoy learning, students tend to improve their learning performance by getting higher grades and performing well in tests and exams.

In addition, the advantage found in this application is the interface design element of the Go Electronic application. By organizing the interface design, we can ensure that users find it easy to use and gain knowledge about digital electronics more effectively. The selection of a background that has harmonious colors and has cartoon elements is more pleasant and attracts the attention of users. Even so, there are still some shortcomings that need to be fixed in order for the Go Electronic application to get a good response from users. Constructing questions in the form of answer choices and writing answers cannot develop the mind because the answer choices are already available. However, confusing the use with the answer will give the impression of a challenge to the user.

Next, the game element also needs to be improved in terms of the time given. This is to avoid wasting time while in the lecture. Therefore, the score has been limited to a low score of five. A long game can also invite users to be more complacent and bored. Finally, although there are advantages and disadvantages in the construction of the Go Electronic application, this application is suitable for university students who need a little entertainment in the addition of knowledge after focusing on purely theoretical learning. Adding that platforms such as Scratch can increase student motivation and engagement in learning.

However, limitations in this study should be critically considered. The small sample size and qualitative approach limit the broader applicability of these findings. With data derived from only three expert interviews, the study's conclusions may not fully reflect the experiences of a larger, more varied population. This narrow focus also limits generalizability across different educational contexts and student demographics. Future research involving larger, more diverse samples and quantitative data analysis could offer a more robust understanding of gamification's effectiveness in digital electronics education, potentially solidifying its utility across broader educational settings.

4 CONCLUSION

As a result, it can be concluded that the objective of the study has been achieved by the researcher. The questions that have been found have also been analyzed more carefully to evaluate the validity of the development of Go Electronic game-based teaching aids for the topic of digital electronics for the subject of electronic technology. The educators aiming to implement similar tools should take actionable steps to optimize game-based learning in digital electronics. Expanding application content with varied question types and levels of difficulty can address different learning paces, strengthening understanding of key topics such as logic gates and Boolean algebra. Incorporating adaptive learning paths and regular feedback could further personalize learning, allowing students to track their progress and remain engaged. Based on the previous studies, it has become an inspiration for references to provide various types of ideas and changes based on the wishes of the students. Research findings from previous researchers related to this study, especially in studies related to the development of the use of teaching aids with an educational concept. Researchers can also feel that these teaching aids can be widely accepted positively by every individual in society. Therefore, teaching aids also need to successfully attract students' interest and teach the topic of digital electronics. The results of the study show that students who are involved in learning using the

Scratch application can develop creativity and logical thinking in themselves. Future research should prioritize scaling this application to multiple institutions and testing it with larger, more diverse student groups to gauge its effectiveness across demographics and learning styles. Such studies could reveal practical insights into the logistical and technical aspects of broader implementation. Comparative research assessing Go Electronic alongside other interactive tools would also clarify which features are most beneficial for learning digital electronics. Moreover, incorporating real-time data analytics could empower educators to refine instructional strategies, making game-based learning even more effective in higher education.

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