

Development and Usability of Bridgetronic as Teaching Aid for The Topic of Electronic Systems in The Invention Subject

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ABSTRACT - The topic of Electronic Systems in the Invention subject involves both theoretical and practical components that help students better understand concepts by applying the theoretical knowledge learned in class. This approach enables students to apply theory in practical situations, reinforcing their understanding. However, teaching methods are still largely limited to conventional, teacher-centered approaches, which hinder students' comprehension and communication skills. Additionally, the lack of sufficient teaching aids and instructional materials affects the overall quality of teaching and learning. Therefore, this study aims to analyze, develop and determine the usability of Bridgetronic as a teaching aid for the topic of Electronic Systems in the Invention subject. This study adopts the ADDIE instructional design model as the main framework and employs a mixed-method approach of qualitative and quantitative to obtain analytical findings in achieving the study's objectives. A total of three Invention's teachers were selected as participants using purposive sampling. Data were collected through interview protocols and checklists and were analyzed using thematic analysis and descriptive methods. The development of Bridgetronic is grounded in two key learning theories behaviorism and constructivism. Behaviorist principles were applied through reinforcement and repetition in circuit connection activities, helping students master basic electronic concepts more effectively via rewards at each game level. Meanwhile, constructivist principles were integrated by enabling students to actively construct new knowledge through hands-on experiences provided by the teaching aid. Overall, this study contributes to teaching innovation in Electronic Systems through the development of a more relevant and 21st-century-oriented instructional tool.

INTRODUCTION

In an era of rapid technological advancement, the education system must adapt to a changing world that demands more effective and relevant learning approaches. One of the biggest challenges in today's education world is ensuring that students understand difficult topics such as Electronic Systems in the Design subject. This topic is not only theoretically challenging but also requires a strong practical understanding. Therefore, an interesting, interactive and easy-to-understand teaching approach is very important to improve students' understanding and help them apply knowledge in real-world situations.

In the context of TVET education, mastery of theoretical and practical aspects is an important foundation in producing skilled and competent human capital. The combination of these two aspects is complementary in the field of Technical and Vocational Education to ensure that students not only

understand concepts academically but are also able to apply them in real-world situations. Teachers play a key role in ensuring effective teaching through an integrated approach. Without the implementation of quality teaching, students are at risk of failing to apply the knowledge learnt in the workplace. According to Ahmad et al. (2015), the weaknesses of the TVET education system also contribute to the failure to produce skilled workers who meet the needs of the industry, especially in sectors based on high technology. This statement is also supported by Nor Roselidyawaty Mohd Rokeman & Che Ghani Che Kob (2025), stating that the success of the TVET curriculum depends greatly on the effectiveness of delivery by teachers.

Furthermore, the absence of modern facilities and sufficient practical training limits students' ability to acquire essential skills. This impacts the effectiveness of Teaching and Learning (PdPc) and causes the gap between theoretical knowledge and industry practice to widen. The advancement of world technology needs to reduce conventional teaching methods that are still teacher centred. This approach makes PdPc one-way and restricts students' active involvement, thus making it difficult for them to understand technical topics such as Electronic Systems (Azam Abd Aziz et al., 2024). Despite the existence of Teaching Aids (ABM), according to a study by Sahaat & Muhamad Nazri (2020), the level of Teaching Aids (ABM) readiness is still moderate and insufficient to support teaching effectively.

The lack of use of interactive ABM, such as simulations, 3D models, digital software or visual tools, causes students to only rely on textbook theory. Mohd Azlan Mohammad Hussain et al. (2023) found that students only passively receive lectures on topics such as Arduino and Micro:bit without using real components. This situation makes it difficult for students to imagine and understand real-world applications of electronic components. Teachers need to provide additional learning resources, such as videos, digital modules, and projects that are based on the Project-Based Learning (PBL) approach, which encourages higher-order thinking skills. According to Yuliana & Susiyawati (2024), a variety of learning resources helps students increase creativity and solve problems more effectively.

Overall, conventional teaching approaches are increasingly irrelevant in modern technology-based education. To ensure that students can better master challenging topics such as Electronic Systems, the development of technology-based ABM is very important. It can make the learning process more interactive, practical, and effective. Innovative ABM development that aligns with the needs of PdPc will help students understand concepts more deeply and hone their skills to meet industry requirements and current technological developments. Therefore, research and development on ABM in the topic of Electronic Systems needs to be implemented comprehensively to ensure the effectiveness of teaching and learning in the subject of Design in secondary schools and TVET institutions.

PROBLEM STATEMENT

In today's era of rapid globalization and technological advancement, the field of education faces increasing pressure to evolve and adapt to the digital transformation shaping all aspects of life. However, many schools and educators continue to rely on conventional, teacher centered methods that emphasize one way knowledge delivery. This traditional approach limits student engagement, reduces interaction, and hinders the development of essential communication and problem-solving skills. When teaching remains dominated by lectures and textbook based explanations, students often struggle to connect theoretical knowledge with the real-world applications, especially in subjects that demand practical understanding such as Design, Innovation and Electronic Systems.

Next, conventional teaching methods that exclude technology from the teaching and facilitation process of teaching have been identified as a major barrier to effective learning. According to Azam Abd Aziz et al. (2024), students frequently face difficulties mastering complex and technical topics because conventional lessons fail to provide hands on experiences. The lack of active participation prevents learners from fully understanding how abstract concepts function in actual contexts. Similarly, Sahaat and Muhamad Nazri (2020), reported that teaching materials and aids for subjects such as Invention subject remain only moderately adequate. While resources exist, they are often insufficient or fail to align with the needs of current pedagogical practices. The continued dependence on textbooks and whiteboards not only limits creativity but also restricts opportunities for students to explore and visualize difficult concepts.

Other than that, the absence of suitable physical and game-based teaching aids further compounds this issue. Learning environments that depend solely on theoretical delivery often result in surface level

understanding, particularly in topics like Electronic Systems that require comprehension of circuits and components. Hussain et al. (2023) highlighted that for topics involving systems such as Arduino and Micro:bit, students are often limited to listening to teacher explanations without access to practical tools that illustrate system operation. Consequently, students remain passive participants rather than active learners. This lack of engagement diminishes both motivation and retention of making it difficult for learners to apply their knowledge in real world of problem-solving scenarios.

In addition, teacher readiness and confidence in integrating technology-based teaching remain low. Studies conducted among teacher trainees at the Institute of Teacher Education (Saleh et al., 2018), revealed that many still prefer traditional method which is teacher centred approaches with minimal use of digital tools. Limited technological literacy and time constraints hinder the development of innovative, student centred teaching practices. Without sufficient exposure to interactive and digital based materials, teachers are unable to design lessons that promote active participation and experiential learning principles central to 21st century education.

Moreover, overreliance on textbooks restricts opportunities for deeper understanding. Textbooks typically lack practical examples like contextual relevance and real-world simulations that can help students grasp abstract electronic principles. According to Yuliana and Susiyawati (2024), providing multiple reference sources such as videos, simulation software and project-based activities can enhance students' potential in particularly of problem solving and creative thinking. However, such resources are rarely implemented in regular classrooms due to the absence of suitable and accessible teaching aids. As a result, students fail to develop critical and innovative thinking skills, both of which are fundamental in Technical and Vocational Education (TVET).

Furthermore, Zulaidah Salsidu et al. (2018), found that students tend to lose interest and become disengaged when lessons rely solely on textbooks and whiteboards, especially for abstract or challenging topics. This situation underscores the urgent need for interactive, game based and technology integrated teaching aids that not only make learning more engaging but also enhance comprehension through hands on experience for students.

Therefore, it is evident that conventional pedagogical practices are increasingly irrelevant in modern education. The lack of effective, interactive and safe physical teaching aids has created a gap between theoretical learning and practical application, particularly in the topic of Electronic Systems under the Invention subject. Addressing this issue requires the development of innovative, user-friendly teaching aids that combine physical interactivity and technological integration. The introduction of a teaching aid such as Bridgetronic teaching aid, puzzle-based tool designed for interactive learning that can bridge this gap. Such innovation aligns with the goals of 21st century education by fostering active participation, promoting deeper understanding and equipping students with essential problem solving and technical skills.

OBJECTIVE

The purpose of this study has been following specific research objectives, which are:

1. To analyze the needs for the development of Bridgetronic as a Teaching Aid for the topic of Electronic Systems in the Invention subject.
2. To develop Bridgetronic as a Teaching Aid for the topic of Electronic Systems in the Invention subject.
3. To determine the usability of Bridgetronic as a Teaching Aid for the topic of Electronic Systems in the Invention subject.

METHODS

This study employs the ADDIE model for product development to create Bridgetronic. This development is guided by the ADDIE model, which consists of five main phases, namely Analysis, Design, Development, Implementation and Evaluation which are suitable for developing technology-based educational products. Learning theory uses the ADDIE model, which has a more systematic, dynamic and synergistic process. Figure 1 shows the conceptual framework of this study.

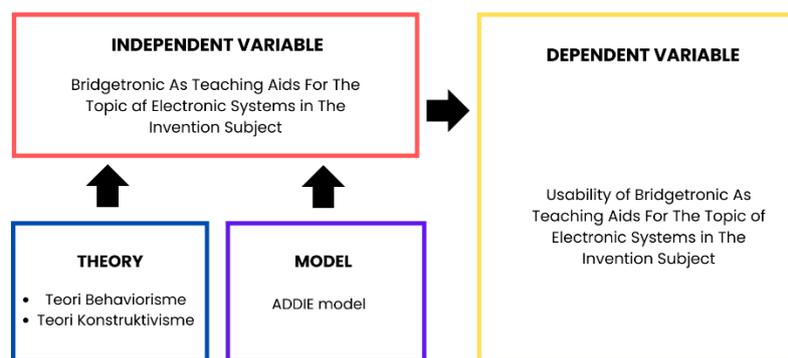


Figure 1. Conceptual Framework of the Study

Research Approach

In this study, a qualitative approach was used in the Analysis phase to identify the needs and important elements in the development of Bridgetronic teaching aids. Next, a quantitative approach was applied in the Development phase to confirm the suitability of the developed elements based on the percentage of data findings. Finally, the qualitative approach was applied again in the Evaluation phase through a semi-structured interview method using an interview protocol as a research instrument. This phase focused on assessing the usability of Bridgetronic as a teaching aid.

Population and Sample

The population in this study involved teachers who teach invention subjects in secondary schools throughout Malaysia. The selection of these teachers was based on certain criteria, namely that they had at least five years of experience in teaching the subject. For the Analysis phase and the Evaluation phase in the ADDIE model, only three invention subject teachers were selected through purposive sampling. This selection allowed the study to be conducted in a more focused manner and within a set period of time.

In addition, the population for the Bridgetronic development objective in this study involved lecturers who were experts in the topic of electronics. Only three lecturers from the Sultan Idris Education University were selected through purposive sampling. The selection of these expert lecturers allowed the data obtained to be more accurate and focused in line with the need to assess the suitability and usability of the Bridgetronic teaching aid in the context of teaching electronics topics in depth and effectively.

Research Instruments

This study used a semi-structured interview method to enable flexible and in-depth discussions based on the respondents' views. The instrument used was an interview protocol that was built based on the study objectives and reviewed by three expert lecturers in the field of electronics with over five years of experience. Jasmi (2012), emphasizes the importance of expert validation in ensuring the accuracy of the instrument's measurement of the studied aspects. The same expert also validated the checklist instrument, which assesses the validity of the Bridgetronic teaching aid. This process ensures that the teaching aid developed meets the learning objectives, is appropriate to the topic content, and meets the aspects of usability, safety and effectiveness in improving student understanding.

Data Analysis Methods

The data analysis methods in this study include thematic analysis and descriptive analysis by percentage. Thematic analysis was used for qualitative data to identify the main themes that are relevant to the study objectives and serve as the basis for designing the Bridgetronic. Meanwhile, quantitative data was analysed using the percentage method through a checklist instrument that assessed the content validity and usability of the teaching aids. Triangulation is employed to combine

qualitative and quantitative data collection instruments, procedures, and analysis within a study. Studies using this technique typically involve quantitative instruments such as tests and questionnaires, together with qualitative instruments such as interview guides or focus group interview guides (Sylvester Donkoh & John Mensah, 2023). This data triangulation approach provides a comprehensive understanding of the effectiveness of the Bridgetronic teaching aid in teaching the topic of Electronic Systems for TVET education group.

RESEARCH FINDINGS

The first phase of the ADDIE model was the Analysis phase, which was carried out to identify the needs for the development of ABM based on the concept of a puzzle game. We obtained the findings through semi-structured interviews with three secondary school of invention subject teachers who had experience teaching the topic of Electronic Systems. We thematically analysed the interview data, categorising it into several main themes that closely aligned with the needs for the development of teaching aid.

Bridgetronic Development Needs a Teaching Aid

Theme 1: Constraints in Teaching the Topic of Electronic Systems

Respondents stated that students face difficulties in understanding the operation of circuit systems and the functions of electronic components due to the lack of sufficient physical teaching aids. This shortage makes it difficult for students to see, touch and test the electronic components themselves that are theoretically discussed in class. Furthermore, limited access to ICT laboratories and electronic materials such as circuit boards, multimeters and electronic components makes the teaching process impossible to implement comprehensively. Teachers also face great challenges in explaining technical concepts without actual practical demonstrations, causing learning to become abstract and difficult for students to understand.

This situation affects the level of student mastery, especially for critical topics in electronic systems that require visual and practical understanding. Therefore, the need for interactive and easy-to-use physical teaching aids is very important to help teachers deliver lessons more effectively and ensure that students understand and master the content more deeply.

Theme 2: Lack of Existing and Effective ABM

Respondents stated that they have used various digital materials such as Canva for visual presentations, PhET for interactive simulations, and quiz platforms such as Quizizz and Kahoot to test students' understanding online. In addition, Tinkercad was also used to provide a basic overview of electronic circuit design virtually. However, respondents emphasized that the use of digital materials alone is still not enough to meet the needs of comprehensive teaching and learning, especially in topics that require practical understanding. They emphasized the importance of providing real ABM that allows students to interact directly with real components and tools. This approach can not only increase the level of student understanding in more depth but also enhance the learning experience through fun and effective practical activities. Therefore, the combination of digital materials and physical ABM is seen as more effective in the context of skills-based TVET education.

Theme 3: Physical Game Element Requirements

All respondents agreed that the physical game element in ABM can attract students' interest because it makes the learning process more fun and not boring. Through activities that involve interaction, such as arranging symbol cards, drag-and-drop activities, and matching, understanding can be actively built. This approach helps students maintain focus and be directly involved in learning instead of just passively listening to the teacher's lecture. Respondents also suggested that the game be designed in several stages, starting from basic to advanced. This feature allows students to learn according to their respective levels of mastery, thus reducing pressure and increasing motivation to keep trying. Game activities can also function as informal assessments that help teachers track the level of student

understanding. Therefore, the integration of game elements in ABM can support the cognitive development and thinking skills of students more effectively.

Theme 4: Implementation of Curriculum and Ergonomics

Respondents emphasised several important aspects in developing teaching aids to be more effective and user-friendly. Among them is compliance with the DSKP content, which ensures that the content is in line with the learning objectives. Material safety is also emphasised, where the filament must be non-toxic, non-sharp and suitable for use by students. The size of the ABM also needs to be ergonomic, not too big or small, so that it is easy to use and store.

In addition, the preparation of a complete user guide to help teachers and students understand how to use teaching aids systematically. Respondents also recommended that the duration of use not exceed 15 minutes to maintain student focus. From a visual point of view, the use of attractive colours and high contrast is recommended to attract student attention. Finally, the addition of safety features such as warning labels or physical protection is suggested to ensure safety during use. All these aspects are important to increase the effectiveness of PdPc.

Bridgetronic Development as a Teaching Aid

This section is a continuation of the requirements analysis in the development of the Bridgetronic. After going through the ADDIE Model Analysis and Design phase, the development of these teaching aids was carried out through a questionnaire method using a checklist instrument. Bridgetronic was developed with 3D printing technology to produce small puzzle-shaped blocks connected to a circuit board. Each design was printed using multi-coloured filaments to represent the functions of different electronic components. The electronic components were then installed on each block according to their functions and arranged on the circuit board for the purpose of testing the usability of the system as a whole. Each block was labelled with a specific alphabet to facilitate arrangement and installation in the correct order, as shown in Figure 2. The usability assessment of Bridgetronic was carried out by three expert lecturers in the field of Technical and Vocational Education.

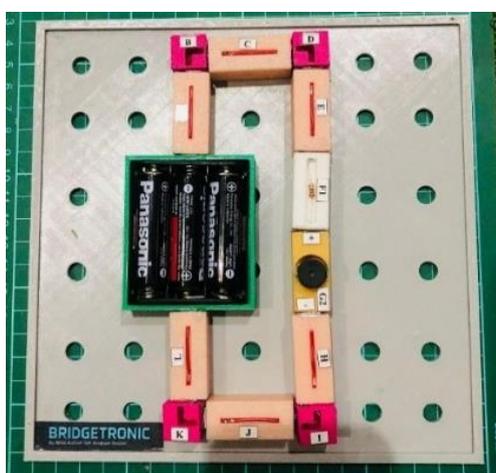


Figure 2 Connecting the labeled puzzle block components

Part A: Electronic Components

Overall, all experts expressed agreement with all five items in this section. The results in Table 1 showed that items A2 to A5 received full agreement of 100% from all experts. This indicates that the technical aspects and preparation of components in Bridgetronic are satisfactory and suitable for use in the teaching and learning process. However, on item A1, only two out of three raters 66.67% agreed that the LED worked well. This situation indicates the need for improvement in terms of connections, LED selection, and technical issues during testing.

Table 1. Items for Part A: Electronic Components

Item	Statement	Agree	(%)	Disagree	(%)
A1	LED is provided and works properly.	2	66.67%	1	33.33%
A2	A buzzer is provided and produces sound.	3	100%	0	0%
A3	A resistor with an appropriate value is used.	3	100%	0	0%
A4	Wires or jumper wires are sufficient and not damaged.	3	100%	0	0%
A5	Power supply (battery) is sufficient.	3	100%	0	0%

Overall, the Bridgetronic's electronic components are at a very good level, with some minor improvements needed to ensure all components function. This finding reinforces the potential of Bridgetronic as an effective teaching aid in teaching Electronic Systems topics.

Part B: Functionality of Electronic Components

In this section, the findings show that all experts fully agreed with each item assessed with a 100% agreement rate, as shown in Table 2. All components, including the function of the LED that lights up when receiving input, the buzzer that operates when the switch is activated, and the role of the resistor in controlling circuit current, were identified to meet the basic requirements in an electronic system. In addition, the effectiveness of the diode and the ability of the battery to supply electric current were also confirmed as working properly.

Table 2. Items for Part B: Functionality of Electronic Components

Item	Statement	Agree	(%)	Disagree	(%)
B1	The LED lights up when given input.	3	100%	0	0%
B2	The buzzer works when the circuit is turned 'ON'.	3	100%	0	0%
B3	Resistors are used to control the current in the circuit.	3	100%	0	0%
B4	Diodes can function only to control the circuit current in one direction.	3	100%	0	0%
B5	Wires or jumper wires can be connected to other electronic components.	3	100%	0	0%
B6	It is possible to connect wires or jumper wires to other electronic components.	3	100%	0	0%

This proves that all components can be connected properly without any technical issues. Overall, Bridgetronic meets the required functional features and is in line with the requirements in the Electronic Systems topic for teaching and learning purposes.

Part C: Circuit Connections

The field expert evaluation showed full agreement on all the items evaluated. The circuit connections in the teaching aids were found to be complete and stable and did not show issues such as crossed wires that could cause short circuits. In addition, the connections complied with the component polarity and were arranged according to the circuit diagram. This aspect is important to ensure safety of use and to improve students' understanding of the principles of correct circuit connection. Based on Table 3, all three experts fully agreed 100% on all items in C1 to C4 related to circuit connection. This assessment proves that Bridgetronic is built with technical features that meet the requirements of circuit connection. This information is important to ensure the effectiveness and safety of teaching and to help students understand the structure of circuits accurately in the topic of Electronic Systems.

Table 3. Items for Part C: Circuit Connections

Item	Statement	Agree	(%)	Disagree	(%)
C1	All circuit connections are complete and stable.	3	100%	0	0%
C2	There are no crossed wires, which could potentially lead to short circuits.	3	100%	0	0%
C3	The circuit connections are made on components that have the correct positive and negative polarities.	3	100%	0	0%
C4	Ensure that the circuit connections align with the provided circuit diagram.	3	100%	0	0%

Part D: Security Features

Safety features are an important element in the development of teaching aids involving electronic components. The use of a low voltage of 4.5V is also considered suitable for secondary school students. This emphasis shows that the design of Bridgetronic has taken user protection into account in the classroom context. Table 4 shows the data analysis of the safety features in the development of Bridgetronic. The four safety items for D1 to D4, which were assessed by three panels of assessors through a checklist, showed 100% full agreement, thus proving compliance with the safety requirements in the design of the teaching aids in the safety aspects required for use in the classroom, especially for practical activities related to electronic systems.

Table 4. Items for Part D: Security Features

Item	Statement	Agree	(%)	Disagree	(%)
D1	No components are exposed to touch.	3	100%	0	0%
D2	All connections are covered or wrapped with insulation.	3	100%	0	0%
D3	Circuits are tested in safe and controlled conditions.	3	100%	0	0%
D4	Use of low voltage (4.5 volts) for student safety.	3	100%	0	0%

Bridgetronic's Usability as a Teaching Aid

The third objective of this study is to evaluate the usability of Bridgetronic in PdPc on the topic of Electronic Systems. This evaluation covers the final phase of the ADDIE model. Semi-structured interviews with three teachers were conducted and the data were analysed using a thematic analysis approach.

Theme 1: Effective Learning Facilitation

All respondents agreed that Bridgetronic plays an important role in helping students understand the topic of Electronic Systems more effectively. Respondent 1 stated that students can more easily master the concept of electronic circuits because they can see and touch their actual components, while Respondent 2 emphasized that the physical block approach attracts students' interest in this challenging topic. This teaching aid also allows students to directly relate theory to practical experience. Respondents stated that students can see the effects of incorrect connections directly, such as an LED that does not light up, thus helping students understand and apply the concept more deeply. Overall, Bridgetronic can act as a facilitator for more effective PdPc in line with the practice-based and student-centered learning approach.

Theme 2: User Friendly and Safe to Use Design

The simple design of the teaching aids, the use of clear colours and labels, and the modular connection system make them easy to understand without special training. Respondents agreed that the simple design of the teaching aids, the use of clear colours and labels, and the modular connection system made them easy to understand without special training. In addition, this teaching aid does not require a direct electrical connection and can be used in any classroom. Its lightweight, non-sharp physical

design, and the use of low voltage also meet safety aspects. It also does not require a direct electrical connection and can be used in any classroom. Its lightweight, non-sharp physical design and the use of low voltage meet safety features.

Theme 3: Increasing Student Motivation and Active Engagement

Bridgetronic has been proven effective in increasing students' motivation and interest in the topic of electronic systems. Respondents stated that students were more active during PdPc when using this ABM because the game approach applied made learning activities more fun and competitive. Respondents explained that passive students were also interested in arranging blocks, and respondents stated that students felt excited and more focused in class. Students were also able to understand the concept of component system operation more easily because they directly saw the connection of blocks in the formation of circuits. This approach is in line with the requirements of 21st-century pedagogy, which emphasizes active, collaborative, and interactive learning.

Theme 4: Supporting the Implementation of Inclusive and Adaptive PdPc

Bridgetronic supports inclusive teaching through a user-friendly design that is suitable for students of all abilities. Clear colours and labels make it easy for students to identify the functions of the blocks, with teacher monitoring to ensure correct circuit connections. The ABM is also flexible, does not require special facilities, is easy to use individually or in groups, and does not require specific training. This feature allows its implementation in various classroom contexts, including those with limited needs. In conclusion, the design of Bridgetronic supports adaptive PdPc in line with the DSKP and the principles of quality and

DISCUSSION

This discussion focuses on the needs analysis, development process and usability evaluation of the Bridgetronic teaching aid designed for the topic of Electronic Systems in Invention subject. The needs analysis, conducted through semistructured interviews with three experienced teachers, revealed that Bridgetronic is highly necessary in secondary school teaching. Teachers highlighted challenges by explaining electronic circuit concepts due to limited physical teaching aids and insufficient electronic components such as breadboards, resistors, LEDs dan so others. Existing digital tools like Quizizz, Canva and PhET Simulator were found to lack tactile learning experiences, emphasizing the importance of tangible teaching aid for technical and hands-on learning.

The development phase, evaluated by subject experts, confirmed that Bridgetronic are safety, functionality and pedagogical standards. All electronic components functioned effectively, with minimal technical issues that were later resolved. The 3D printed design of the Bridgetronic teaching aid ensures safety and structural precision. However, the printing process requires a considerable amount of time to complete and posing a challenge in meeting the designated development timeline.

In terms of usability, thematic analysis of expert feedback indicated that Bridgetronic facilitates effective learning by bridging theory and practice in class. Its game based elements increase student motivation, engagement and reflective learning. These findings align with previous studies in literature review which highlight the motivational benefits of game based and hands-on learning.

Overall, Bridgetronic proves to be a pedagogically effective, practical and student centred teaching aid that enhances conceptual understanding, promotes active learning and supports the DSKP's objectives for innovative teaching in Malaysia's technical education context.

CONCLUSION

In conclusion, this study reports findings based on three main objectives which is development needs a teaching aid, developing the Bridgetronic teaching aid and Usability as a teaching aid. The results show that Bridgetronic effectively meets the needs of teachers and students in enhancing

understanding the topic of Electronic Systems through an interactive puzzle-based approach. Its tangible and practical design enables teachers to clarify theoretical concepts more effectively while providing students with meaningful hands-on experiences. This facilitates deeper conceptual understanding, encourages reflective learning and strengthens the transfer of knowledge from theory to practice. The integration of game-based elements within Bridgetronic teaching aid successfully enhances student motivation and engagement by transforming passive learners into active participants. Students displayed higher enthusiasm and involvement when given autonomy to explore and experiment independently. Although several improvement areas were identified such as adding more components and increasing mastery levels the development process faced challenges involving time, cost, design and 3D printing limitations. Despite these challenges, Bridgetronic teaching aid offers valuable implications for the implementation of student centred teaching and learning in line with the DSKP requirements. Overall, the Bridgetronic teaching aid demonstrates significant potential to enhance innovative and engaging instructional strategies in technical education, particularly for invention subjects in Malaysia.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

AUTHORS CONTRIBUTION

Aqilah Teh Nadjwa Roslan: Conceptualization, Methodology, Software. **Fardila Mohd Zaihidee:** Supervision, Writing- Original draft preparation. **Aqil Roqwaan Roslan:** Visualization, Investigation. **Fayyadhatul Alya Ahmad Misnun:** Data curation. **Zon Fazlila Mohd Ahir:** Software, Validation. **Wan Nurlisa Wan Ahmad:** Writing- Reviewing. **Tang Jing Rui:** Writing- Editing.

AVAILABILITY OF DATA AND MATERIALS

Data available on request from the authors.

DECLARATION OF GENERATIVE AI

During the preparation of this work, the author(s) used ChatGPT to enhance the clarity of the writing. After using the ChatGPT, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

ETHIC STATEMENTS

Ethical clearance for this study was obtained from the University Ethics Committee, Universiti Pendidikan Sultan Idris. The study involved minimal risk to participants, and all ethical principles related to voluntary participation, confidentiality, and data protection were fully observed.

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