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Development Of An Internet Of Things-Based Scoreboard Learning Media For Mechatronics Control Technique Education

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Abstract

This research is motivated by the need for students in the Electronics Engineering program to master technology that meets the demands of the workforce, one of which is the Internet of Things (IoT). However, based on observations and interviews with Control Engineering teachers at SMK Negeri 1 Bawang, this technology has not been optimally taught. Therefore, there is a need to develop IoT-based learning media. This study aims to develop an IoT-based scoreboard learning media, and to evaluate its feasibility, practicality, and effectiveness.

The research employs the Research and Development method using the ADDIE model, which includes five stages: Analyze, Design, Development, Implementation, and Evaluation. Data were collected using media feasibility assessment sheets, material feasibility assessment sheets, product practicality questionnaires, and tests. The data analysis methods used in this study include (1) categorical analysis to determine the feasibility level of the learning media; (2) reproducibility and scalability coefficients to determine the practicality of the learning media; and (3) N-Gain to measure the effectiveness of the learning media.

The results show that the developed learning media has a high level of feasibility. The practicality of the product was rated as practical based on user assessments. Additionally, the improvement in student learning outcomes, as indicated by the N-Gain scores, demonstrates that the learning media is effective for use.

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INTRODUCTION

Vocational High Schools are a type of formal secondary education aimed at graduating students who master technology according to the needs of the workforce. One of the technologies that needs to be taught in vocational high schools is the Internet of Things (IoT). According to the World Economic Forum's Future of Jobs Survey 2018, four technologies are predicted to dominate: high-speed mobile internet, artificial intelligence, big data analytics, and cloud technology. The survey indicates that 92% of companies in Indonesia will adopt user and entity big data analytics, 86% will adopt the Internet of Things, and 82% will adopt machine learning. However, interviews with Mechatronics Engineering teachers at SMK Negeri 1 Bawang reveal that IoT has not been optimally taught, indicating a need for the development of IoT-based control technique learning media for Mechatronics Control Technique education.

According to Berdisati & Saefuddin (2014), learning is a process of adding knowledge and insight through a series of conscious activities, leading to positive changes in skills, proficiency, and knowledge. Vocational high school education aims to produce skilled graduates ready for work with various competencies that align with the advancements in science and technology (Hadam, 2017). Learning at vocational high schools is conducted to develop cognitive, psychomotor, and affective competencies. Gough (2010) states that vocational education aims to acquire general knowledge and skills relevant to the workforce. Phommavongsa et al. (2018) agree, stating that the characteristics of learning in vocational high schools integrate knowledge, skills, and attitudes to achieve specific competencies. One of the competencies in vocational high schools is Mechatronics Engineering.

The Mechatronics Engineering competency, now part of the Electronics Engineering Program with a focus on Mechatronics under the new curriculum, aims to prepare graduates ready to enter the workforce in manufacturing technology and engineering. Mechatronics is a multidisciplinary field that combines mechanics, electronics, and informatics (Anwar et al., 2016). One element in the Mechatronics Control Technique curriculum includes control system components/equipment circuits, electrical motor control circuit installation, PLC/microcontroller programming based on equipment/machine process mechanisms, Human Machine Interface (HMI) programming, and interconnecting PLCs/microcontrollers as a data communication network.

Control engineering or control systems refer to devices (or a collection of devices) used to manage, command, and regulate the state of a system. A control system allows specific inputs to be used to control outputs with defined values, order processes, or produce outputs under certain conditions (Kurniawan et al., 2013). Control engineering includes three main elements: input, process, and output. An example of control technology is the Internet of Things.

According to Efendi (2018), the Internet of Things is a concept where data transfer occurs between objects using an internet connection. These objects can be machines or humans as users. The IoT can be applied to identify, track, locate, monitor objects, and trigger related events automatically and in real-time remotely. It can be used anywhere as long as there is an internet connection. IoT systems are structured with two management architectures: event-based and time-based. Event-based means data is sent when there is activity/data change on the sensor, while time-based means data is continuously sent at set intervals (Aleksandrovičs et al., 2016). The effective learning of this technology in vocational high schools can be maximized using appropriate learning media.

Learning media in vocational high schools should align with the tools or machines used in the workplace (Prosser & Quigley, 1950). This alignment makes it easier for students to achieve the expected competencies. Effective learning media can enhance the quality of learning. Educators can categorize the learning media used into several types. The development of learning media should adhere to certain principles. According to Nurseto (2011), learning media should be developed following the “VISUALS” principles: visible, interesting, simple, useful, accurate, structured. One example of learning media that can be developed for practical learning in vocational high schools is a visual aid. Visual aids can be designed to reflect everyday equipment, such as digital scoreboards.

A scoreboard is an information medium used to display scores in a competition. Displaying scores directly can prevent cheating in scoring. Digital scoreboards are considered more effective and efficient than conventional scoreboards (Triyanto et al., 2021). The scoreboard developed for this learning media uses a seven-segment display. In addition to the seven-segment display, other components can be used as learning tools for students to assemble and program components. IoT-based scoreboard learning media is needed to enhance the knowledge and skills of students in building connections between microcontrollers. Therefore, this study aims to develop such a learning media product, and evaluate its feasibility, practicality, and effectiveness.

METHODS

Type of Research

The IoT-based scoreboard learning media in this study was developed using Research and Development (R&D) methodology with the ADDIE development model. The ADDIE model was chosen because of its simplicity (basic development stages) and systematic structure, making it easy to understand through its stages of analysis, design, development, implementation, and evaluation (Alodwan & Almosa, 2018).

Research Procedure

The ADDIE development model consists of five stages: Analyze, Design, Develop, Implement, and Evaluate (Branch, 2014). These stages form a cycle that must be completed for each stage. The steps involved in this cycle include: (1) the analysis stage, conducted to identify problems that occur during learning; (2) the design stage, conducted to create the design of the product to be developed. The product design is tailored to the learning outcomes analysis, learning objectives, and main learning materials. The process involves compiling development needs, designing hardware, creating an application as the controller, and drafting a module; (3) the development stage, where the media is created according to the design; (4) the implementation stage, where the plan is executed in the Mechatronics Control Technique class for Grade XI in the Mechatronics Engineering Program at SMK Negeri 1 Bawang; and (5) the evaluation stage, conducted in the form of formative and summative evaluations. Formative evaluation is carried out during the development process to assess the feasibility and practicality of the learning media. Summative evaluation is conducted at the end of the development process to determine the effectiveness of the learning media.

Data Collection, Processing, and Analysis Techniques

The data collection techniques used in this study are: (1) expert judgment by lecturers and expert teachers in electronics to obtain data on the feasibility of the learning media; (2) questionnaire data collection to obtain data on the practicality of the IoT-based scoreboard learning media; and (3) tests to determine the effectiveness of using the learning media in improving student learning outcomes.

The instruments used to collect data are: (1) learning media feasibility assessment sheets (media and material feasibility); (2) product practicality questionnaires; and (3) tests. The research instruments will yield valid, accurate, and reliable data after passing validity and reliability tests. Instrument validity tests are conducted to verify the accuracy of the instruments in achieving measurement objectives, while reliability tests determine the consistency of measurements over repeated trials.

The validity test for the media feasibility assessment sheets in this study uses the Content Validity Ratio (CVR) method. According to Lawshe (1975), the CVR method is effective for instrument validation analysis with expert judgment. An instrument is considered valid if it achieves a CVR value above 0.99. If valid items do not meet the target of $r \geq 0.99$, the obtained value is compared to the minimum value based on the number of experts used.

The material feasibility instrument validity analysis results show that all 26 items in the material feasibility instrument are valid. For the media feasibility instrument, out of 32 items, one item is invalid. The valid items are then tested for reliability using the percentage of agreement test. The percentage of agreement indicates how consistently observers or raters give the same assessment of an object or phenomenon. The results are then categorized as reliable or not. An instrument is considered reliable if it achieves ≥ 75% (Borich, 1994).

The reliability analysis results for the material feasibility instrument for material experts, based on the percentage agreement, show a value of 100%. The media feasibility instrument reliability analysis for media experts shows a percentage agreement of 96.87%. Therefore, it can be concluded that the media and material feasibility assessment instruments are reliable.

The validity test for the practicality of the learning media instrument was conducted by calculating the point-biserial correlation. According to Friedenberg (1995), in the development and construction of research instrument scales, a minimum correlation coefficient of 0.30 is used. Therefore, any item with a correlation less than 0.30 can be excluded, and only items with a correlation greater than 0.30 will be included in the test instrument. The closer the correlation is to one (1.00), the better its consistency (validity).

The results of the point-biserial validity test indicated that 24 out of 27 items in the product practicality instrument were valid. For the test instrument, 30 items were valid with a point-biserial correlation coefficient greater than the r-table value of 0.3388. The valid items were then analyzed for reliability using the KR-20 equation. According to Riwidikdo (2010), an instrument is considered reliable if it has a reliability coefficient of at least 0.7. Based on the reliability calculation results, it can be concluded that the product practicality questionnaire instrument is reliable with a high category, as it has a reliability coefficient of 0.750 (greater than 0.7). The test instrument is also deemed reliable with a reliability coefficient of 0.731 (greater than 0.7).

The collected data were then analyzed using the following techniques: (1) descriptive analysis to determine the feasibility of the learning media; (2) analysis of the reproducibility coefficient (Kr) and scalability coefficient (Ks) to assess the practicality of the learning media; and (3) N-gain score analysis to evaluate the effectiveness of the learning media.

RESULTS AND DISCUSSION

The needs analysis for the learning media revealed that the current learning media for Mechatronics Control Techniques at SMK Negeri 1 Bawang is limited to controlling lights through the Blynk application. The use of the Blynk application as an interface has limitations in its data input and output. The widgets used in the Blynk application require energy to activate. Once the free energy is depleted, users need to purchase more energy. This indicates that there is a need for a more flexible learning media that can be developed further and uses new technology. The developed learning media includes a scoreboard hardware, an Android application, and a teaching module.

The design of the IoT-based scoreboard learning media includes the design of the scoreboard, the application, and the teaching module. The scoreboard design, controlled via an application over the internet, consists of the electronic component wiring diagram, the mechanical design of the scoreboard, the scoreboard display design, and the programming flowchart design. Below is the design of the Electronic Component Wiring Diagram:

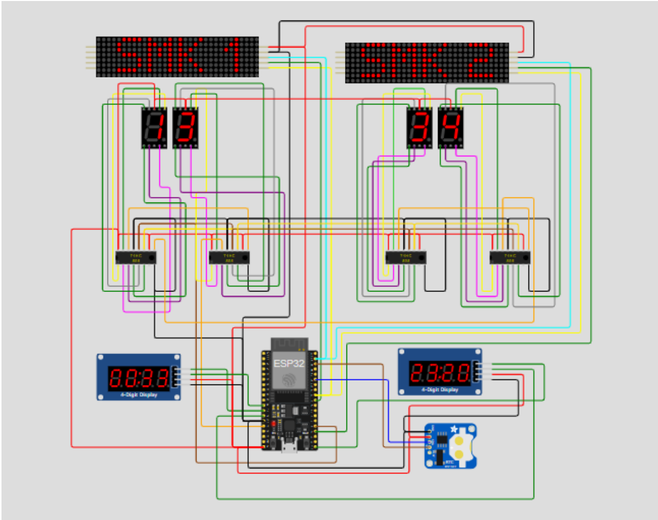

Figure 1. Design of the Electronic Component Wiring Diagram

The design of the Android application used to control the scoreboard and other features aims to create an effective and user-friendly application by considering efficiency and effectiveness during its development. The application design includes creating a storyboard and designing the application interface. Below are the results of the application design:

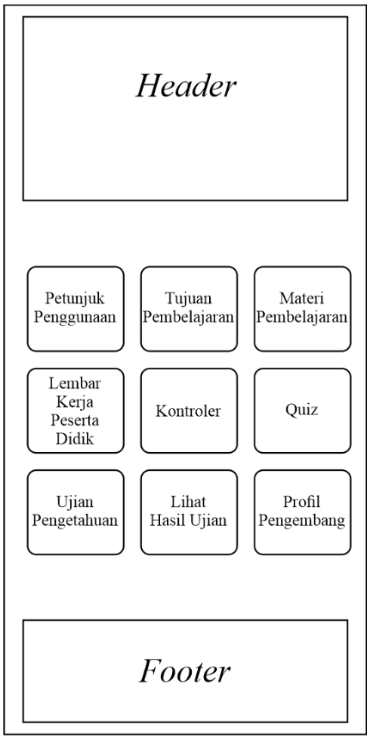

Figure 2. Storyboard of the Home Page

Figure 3. Home Page Interface Design

The teaching module for the IoT-based scoreboard learning media includes objectives, steps, learning media used, and assessments needed for learning. The teaching module is designed as a guide to implementing the media in learning. The module design stages include the framework design of the teaching module and the design of the module's display elements. The framework consists of the cover, general information, core competencies, and appendices. General information includes the module creator's identity, initial competencies, Pancasila student profile, and learning facilities and infrastructure. The core components include: 1) learning objectives; 2) indicators of learning objectives achievement; 3) learning steps; 4) assessment; 5) enrichment and remedial activities; and 6) reflection.

The development stage of the IoT-based scoreboard learning media includes the development of the scoreboard, the application, the teaching module, and the student worksheets (LKPD), and media validation through evaluations by media experts and subject matter experts. This development process follows the design results from the previous stage. Below is the final product of the learning media developed in this study:

Figure 4. Final Product of the IoT-Based Scoreboard Learning Media

The feasibility of the IoT-based scoreboard learning media was determined based on evaluations by two media experts and two subject matter experts. The feasibility data were obtained from the expert evaluations using a questionnaire with a Likert scale, which was converted into quantitative data. The feasibility percentage data were translated into qualitative data based on a measurement scale with categories: 1) 0%-25%: very unfeasible; 2) 26%-50%: unfeasible; 3) 51%-75%: feasible; and 4) 76%-100%: very feasible (Sugiyono, 2017).

Table 1. Total Score and Percentage of Material Feasibility Calculation

Aspect	Total Score per Aspect		Maximum Score	Percentage (%)	
	Expert 1	Expert 2		Expert 1	Expert 2
Material Quality	100	91	100	100	91.00
Usefulness	30	29	30	100	96.67
Overall Aspects	130	120	130	100	92.31
Average Feasibility of Expert 1 and Expert 2				96.2	

Based on the material feasibility analysis, it is found that the evaluations by the two subject matter experts are above the ideal average. The first subject matter expert rated the material at 100%, categorizing it as "Very Feasible," and the second expert rated it at 91%, also categorizing it as "Very Feasible" in terms of material quality. The usefulness aspect evaluation by the subject matter experts resulted in "Very Feasible" with the first expert rating it at 100% and the second at 96.67%. Overall, the evaluation of all aspects by the two experts resulted in an average score of 96.2%, categorizing the IoT-based scoreboard learning media as very feasible.

Table 2. Total Score and Percentage of Media Feasibility Calculation

Aspect	Total Score Per Aspect		Maximum Score	Percentage (%)	
	Expert 1	Expert 2		Expert 1	Expert 2
Display	48	53	55	87.3	96.36
Technical	44	48	50	88	96.00
Usefulness	48	49	50	96	98.00
Overall Aspects	140	150	155	90.3	96.77
Average Feasibility of Expert 1 and Expert 2				93.5	

The media feasibility test results for the IoT-based scoreboard learning media show an average score of 93.5% across all aspects, categorizing it as very feasible. According to Table 2, the first media expert gave a percentage score of 87.3%, categorizing it as "Very Feasible," and the second expert gave a score of 96.36%, also categorizing it as "Very Feasible" in terms of display aspects. The technical aspect evaluation by the media experts resulted in "Very Feasible," with the first expert rating it at 88% and the second at 96%. The usefulness aspect evaluation resulted in "Very Feasible," with the first expert rating it at 96% and the second at 98%.

The implementation of the developed product in learning was carried out after it was deemed feasible by media and subject matter experts. The implementation of the IoT-based scoreboard learning media was conducted with students from the XII TE 1 class of the Mechatronics Engineering Program at SMK Negeri 1 Bawang, involving 32 students as respondents. The implementation stage followed the learning flow outlined in the teaching module. Generally, the implementation activities included a pre-test, learning with the IoT-based scoreboard learning media, and a post-test.

Figure 5. Implementation of the Learning Media

After completing the learning process using the IoT-based scoreboard learning media, students filled out the product practicality questionnaire. The questionnaire data were then analyzed for reproducibility coefficient (Kr) and scalability coefficient (Ks) to determine the practicality of the learning media. The media is considered practical if the Reproducibility Coefficient (Kr) is above the practicality threshold of 0.90. The Scalability Coefficient (Ks) meets the threshold if it is above 0.60 (Singarimbun, 2011). The calculation results show a Kr score of 0.931 and a Ks score of 0.856, meeting the practicality requirements of Kr > 0.90 and Ks > 0.60. Overall, the practicality test results indicate that the IoT-based scoreboard learning media meets the expected practicality standards. Akker (1999) stated that one of the goals of development research is to promote the scientific and practical aspects of the final product.

Evaluation was conducted at the end of the study to determine the effectiveness of the learning media. The effectiveness of the IoT-based scoreboard learning media was measured using the gain score based on the mode obtained from pre-test and post-test scores. The N-Gain score categories are interpreted as follows: 1) less than 40%: not effective; 2) 40%-55%: less effective; 3) 46%-75%: quite effective; and 4) greater than 76%: effective (Arikunto, 1983). The data analysis results show that the N-Gain score for the students pre-test and post-test was 76.4%. Thus, it can be concluded that the use of the IoT-based scoreboard learning media effectively improves students understanding of mechatronics control techniques.

This study's results align with research by Anam et al. (2023), which found that IoT principles and learning media can improve students competence, with an average pre-test score of 58.4 and a post-test score of 76.16. Another study by Rao & Elias-Medina (2024) developed an IoT system for a hospital laboratory to enhance IoT understanding among graduate students at Fairleigh Dickinson University.

CONCLUSION

Based on the research results, it can be concluded that the IoT-based scoreboard learning media developed using the ADDIE model is feasible, practical, and effective for teaching Mechatronics Control Techniques. The feasibility of the material and media is categorized as very feasible, with an average material feasibility score of 96.2% and an average media feasibility score of 93.5%. The material feasibility includes aspects of material quality and usefulness, while the media feasibility encompasses technical aspects, appearance, and usefulness. The practicality of the learning media is determined based on the reproducibility coefficient (Kr) calculation, which yielded a score of 0.931 (greater than 0.90), and the scalability coefficient (Ks) calculation, which yielded a score of 0.853 (greater than 0.60). The effectiveness of the learning media is determined based on the N-Gain score effectiveness test results of 76.4%, which, according to the N-Gain effectiveness interpretation table, falls into the effective category.

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