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Development of Smart Building Training Kit for Control System Competencies in Vocational High Schools

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Abstract

The unavailability, lack of updates and inappropriateness of learning media results in low-quality learning outcomes. The right learning media is an important part of the learning process, especially practicum learning in Vocational High School (VHS). The objectives of the research are to obtain: (1) Products in the form of smart building training kits as learning media equipped with Supervisory Control and Data Acquisition (SCADA) system based on Industrial Internet of Things (IIoT) for VHS in learning control systems; (2) The feasibility level of the training kit; (3) The effectiveness of the use of training kits. Development research refers to the ADDIE model developed by Branch. The study results are as follows: (1) The product in the form of a training kit consists of a component training kit and a simulator equipped with a job sheet and a manual. (2) The training kit is considered very feasible. The expert assessment of the feasibility of the product is 95.5% (very feasible category). The teacher's user response gave a rating of 95.5% (very feasible category). The user response by graduates gave an assessment of 90.8% (very feasible category). (3) The use of training kits has significant effectiveness on students' learning outcomes based on the results of the Paired Sample T-test and Independent Sample T-test with a sig value (2-tailed) (0.000) < 0.05. It can be concluded that a smart building training kit is an appropriate, very feasible, and effective learning medium for use in learning control systems.

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INTRODUCTION

Automation control technology has developed rapidly. The latest automation control technology enables machine-to-machine and human-to-machine connectivity. Smart building is one of the fields of application of automation control technology. The application of technology in smart buildings is expected to provide the best service to humans and the environment [1]. Smart building management is divided into 3, specifically users, owners, and environments to access systems and drivers [2]. The smart building system consists of: (1) heating, ventilation, and air conditioning (HVAC); (2) light; (3) energy; (4) security; (5) telecommunication; (6) fire prevention and fighting; (7) vertical transportation; (8) hydraulic [2], [3]. The existence of smart building management to be more effective and efficient in managing building resources [4], [5].

The Supervisory Control and Data Acquisition (SCADA) system in smart buildings is used for monitoring and controlling installed devices [6]. Accessibility of monitoring and control according to the account level consisting of users, owners and environments. SCADA, based on the Industrial Internet of Things (IIoT), allows control system components with a large number and high level of complexity to be monitored and controlled from anywhere and anytime [7], [8], [9]. The massive development and use of control technology have led to an increase in the need for manpower in this field. The search results for job vacancies in July 2024 for control system technicians on online sites have obtained quite a lot of results. Some of the competency requests requested by the vacancy include: designing, assembling, operating, maintaining and repairing control systems based on Programmable Logic Controller (PLC). In addition, it can master Human Machine Interface (HMI), Inverter, IoT, KNX, and SCADA.

Job opportunities in the field of control and government support have not been fully absorbed by vocational high school graduates. Unemployment of vocational school graduates is caused by the quality of graduates not meeting the demands of the world of work [10]. The competencies that must be possessed by vocational school graduates are hard skills in the form of work skills according to competencies and soft skills in the form of the ability to handle and take advantage of change [11], [12]. The vocational learning process is not only effective, but it must also be able to provide real experiences, such as those in the industrial world [13], [14], [15]. Students have difficulty understanding the material due to the limitations of learning media [16]. Quality vocational learning media is urgently needed in vocational learning to create a good quality of learning [17]. Inappropriate learning media causes the learning process not to be optimal [18] [19], and the quality of student learning outcomes is low [20]. The learning process takes a long time. Students cannot explore the material further due to the lack of available learning resources. Another impact is in the form of low interest in learning students [21], which can be found during the work on practical assignments and reports on the results of practice.

Based on the presentation of ideal and actual conditions in the field related to the learning media in the control system of the Electrical Power Installation Engineering (EPIE), this study tries to develop the right learning media. Learning media is developed in the form of training kits [22]. The form of a prototype facilitates students to get an overview of the implementation of the control system in the field [23], [24]. Learning media in the form of training kits to facilitate learning to be more effective and efficient [25], [26], [27], [28]. Learning becomes more effective because students can observe and do practicum directly [29], [30], [31], [32]. Learning by conducting simulations and doing practicum has a learning absorption power of 90% or the highest based on Dale's experience cone [15]. The training kit is designed into two units, namely, a simulator unit and a component unit. Component units for basic learning and simulator units for final or advanced learning. The two training kit units are to facilitate the learning stages from basic to advanced.

Research pays attention to relevant research to support research. Relevant research includes: Communication across IoT platforms in smart buildings [33], Application of IoT-based SCADA for air conditioning [34], Design of HMI trainers as learning media [35], Design of industry-oriented PLC learning media [36], Internet of things for energy systems [37], IoT applications in buildings [38], [39] and trainer kits of smart buildings for lighting installations [40]. The smart building training kit was developed to learn how to concentrate on EPIE expertise. The scope of training kits in smart buildings includes: lighting systems, HVAC systems, hydraulic systems, and security systems.

METHODS

This research was a type of research and development. This research used the ADDIE model from Branch [41]. The ADDIE model has five stages, specifically, analysis, design, development, implementation, and evaluation, attached to each stage. Participants came from 4 districts in the former district of Madiun, East Java, consisting of 29 teachers, 55 graduates, and 69 students. The research process with the ADDIE model can be seen in Figure 1.

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Research Stages

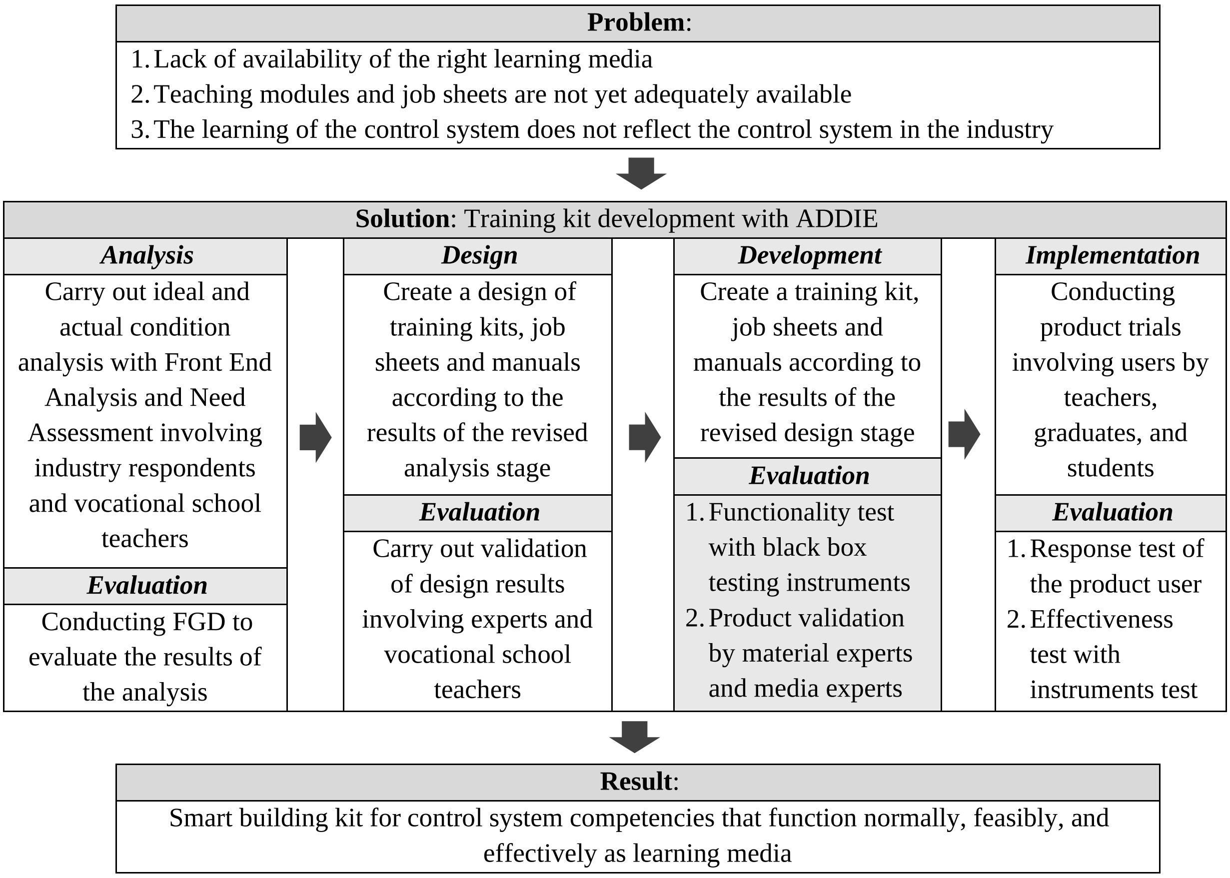

Figure 1. Smart Building Training Kit Development Procedure

The analysis stage identifies obstacles or problems in the field that cause the gap between the conditions that occur and the ideal conditions [42], [18]. Data was collected by conducting interviews and observations from 10 EPIE teachers and 5 EPIE graduates who work in the automation industry. Participants came from 4 VHS in Madiun, Magetan and Ponorogo districts. Evaluation at the analysis stage will be carried out by conducting a Focus Group Discussion (FGD). FGD activities evaluate the data that has been obtained to formulate training kits and supporting components. The FGD consisted of teachers who taught PLC in the Madiun, Magetan, and Ponorogo districts. This activity also examines the learning objectives to be achieved based on the curriculum, National Work Competency Standards (NWCS) and industry needs. Researchers design training kits and equipment at the design stage according to the FGD results. There are three designs, specifically, the design of the training kit, job sheets for students, job sheets for teachers and training kit manuals. Evaluation at the design stage by consulting with experts and peers regarding design suitability. Design conformity refers to the results of the evaluation of the analysis stage and the development of the feasibility assessment instrument.

The development stage consists of the preparation stage, the manufacturing stage and the checking stage. The preparation stage is carried out by preparing the tools and materials needed, especially for the training kit. At this stage, they also prepare materials for teaching modules. Furthermore, the manufacturing stage consists of a process, namely the creation of a training kit, the creation of teaching modules and the creation of a guidebook. Evaluation at the development stage is (a) the checking stage and (b) the stage of validation or assessment from experts. The checking stage is conducted by black box testing on the training kit. Checking is also done by trying a training kit with a teaching module. The validation stage is carried out by material experts and media experts. The implementation stage is carried out by testing the users. The implementation stage consists of 3 stages, namely (a) user trials by teachers, (b) user trials by graduates, and (c) User trials by students. Evaluation at the implementation stage by asking respondents to give responses as product users. Evaluation of quasi-experimental trials by providing a pretest and posttest and conducting a series of t-tests to get answers to the proposed hypothesis.

Instrument and Analysis

Data collection was carried out using questionnaires, observations, interviews and tests [42], [43], [44], [45]. The questionnaire instrument consists of a functionality questionnaire, a questionnaire for expert validation, a questionnaire for user responses by teachers, and a questionnaire for alumni user responses. Initial data was obtained when observing PLC learning activities/control systems in the classroom. Data collection techniques in the form of interviews are used to obtain data for FEA needs. Qualitative data derived from observations and interviews were processed in FGD activities. Data collection techniques in the form of tests are used to obtain data related to the effectiveness of the developed product.

Descriptive statistical data analysis techniques are used to analyze data related to the feasibility of the training kit. Feasibility data from respondents was processed using (1). Table 1(a) is used to interpret the data with a rating scale to obtain feasibility categories. Effectiveness test using the pretest posttest control group design model. Data analysis used paired sample T-test, Independent sample T-test and N-Gain [45]. The design of the effectiveness test can be seen in Table 1(b).

$$\text{Feasibility percentage (\%)} = \frac{\sum Score\ obtained}{\sum Maximum\ score} x100\% \quad \text{.........................} \quad (1)$$

Table 1. Respondent Assessment Result Feasibility Category and The Design of the Effectiveness Test

(a) Feasibility Category

	Feasibility Percentage (%)	**Category**
1.	0-25	Very unfeasible
2.	26-50	Unfeasible
3.	51-75	Feasible
4.	76-100	Very feasible

(b) The Design Test

Group	**Pretest**	**Treatment**	**Posttest**
1. Experiment	A1	Using Training Kit	A2
2. Control	B1	Using Konvensional Media	B2

Note: *A1: Experiment group pretest; B1: Control group pretest, A2: Experiment group posttest, B2: Control group posttest*

RESULT AND DISCUSSION

Research Results

The analysis stage identifies obstacles or problems in the field that cause a gap between the conditions that occur and the ideal conditions. At this stage, it also analyzes the supporting potentials so as to get the right solution. Data was collected by conducting interviews and observations with industrial practitioners, teachers of control systems subjects, and alumni of EPIE. Evaluation at the analysis stage by carrying out FGD. FGD activities evaluate the data that has been obtained to formulate training kits and supporting components. The FGD consisted of teachers who taught PLC in the Madiun, Magetan, and Ponorogo districts. This activity also examines the learning objectives to be achieved based on the curriculum, NWCS and industry needs.

The design stage is carried out by designing training kits and teaching modules in accordance with the results of the evaluation of the analysis stage. Three designs will be made, namely the design of the training kit, the teaching module for students, the teaching module for teachers and the training kit guidebook. Evaluation at the design stage by consulting with experts and peers regarding design suitability. Design conformity refers to the results of the evaluation of the analysis stage and the development of the feasibility assessment instrument. The final design of the simulator unit training kit is shown in Figure 2(a). The final design of the component unit training kit is shown in Figure 2(b).

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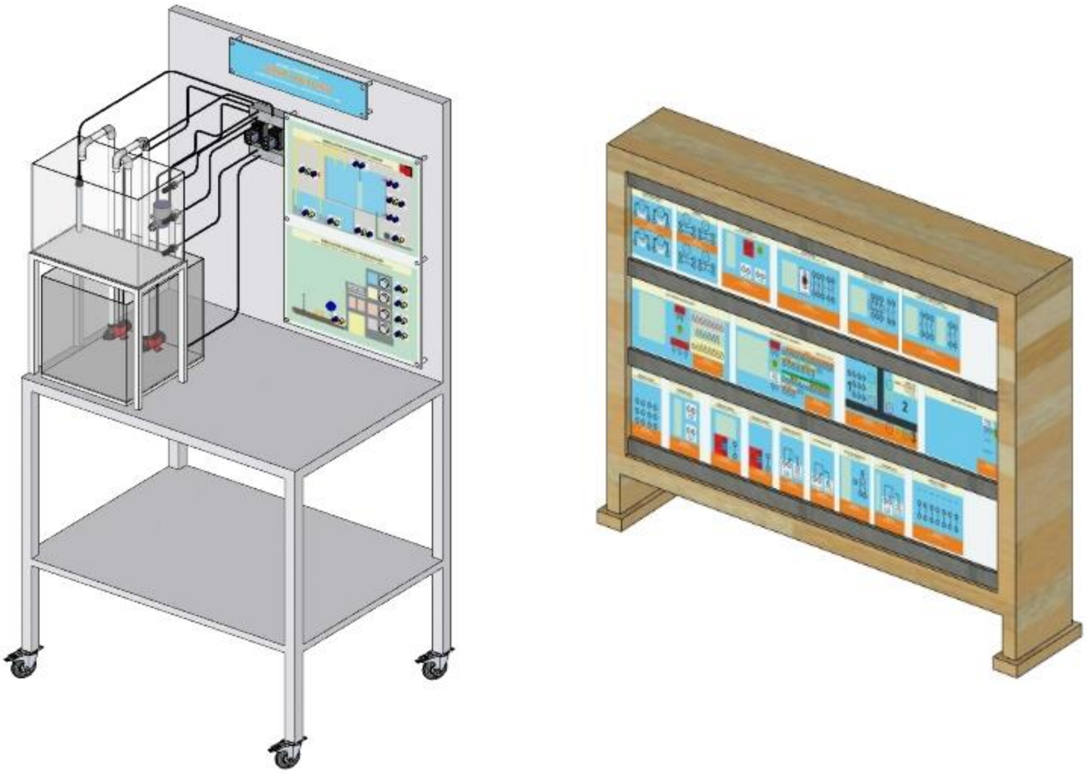


(a) (b)

Figure 2. (a) Simulator Unit Design for Advanced Learning on HVAC Systems, Lighting Systems, Security Systems, and Hydraulic Systems (Water Level Control); and (b) Component Unit Design for Basic Learning in Electro-Mechanics, PLC, Inverter/VFD, SCADA, and IIoT

Figure 3. Smart Building Training Kit Product Equipped with SCADA Based on IIoT

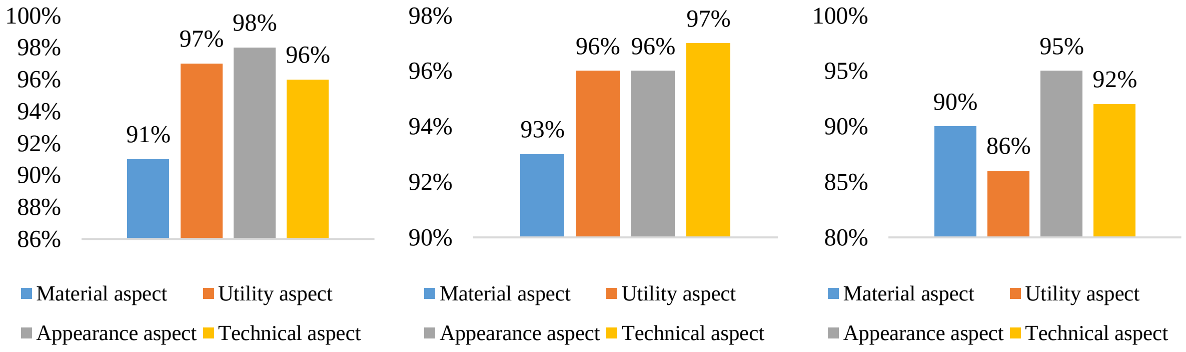
The development stage consists of the preparation stage, the manufacturing stage and the checking stage. The preparation stage is carried out by preparing the tools and materials needed, especially for the training kit. At this stage, they also prepare materials for teaching modules. Furthermore, the manufacturing stage consists of a process, namely the creation of a training kit, the creation of teaching modules and the creation of a guidebook. Evaluation at the development stage is (a) the checking stage and (b) the stage of validation or assessment from experts. The checking stage is conducted by black box testing on the training kit. Checking is also done by trying a training kit with a teaching module. The validation stage is carried out by material experts and media experts. The results of development in the form of training kit products are shown in Figure 3. The implementation stage is carried out by testing the users. The implementation stage consists of 3 stages, namely (a) user trials by teachers, (b) user trials by alumni, and (c) User trials by students. Evaluation at the implementation stage by asking respondents to give responses as product users. Evaluation of quasi-experimental trials by providing a pretest and posttest and conducting a series of t-tests to get answers to the proposed hypothesis.

Discussion

This research produced a product in the form of a training kit equipped with a job sheet and a guidebook. The training kit is made in 2 units, namely the component board and the simulator board. Component board units are used to facilitate learning on basic materials. Meanwhile, the simulator board unit, which is a miniature control process in a smart building, is used to facilitate learning on advanced or complex materials. The training kit has electro-mechanical, PLC, VFD/Inverter, Smart Building and IoT-based control coverage. The scope of control system competencies includes planning, preparation, installation, operation, evaluation and troubleshooting. The presentation of the material is packaged with the order of material or practicum assignments from easy to difficult and from simple to complex.

The results of the development of learning media are in the form of training kits so that students can interact directly in the learning process. The results of the development are in accordance with the opinion of [15] that learning by conducting simulations and doing practicum has a learning absorption capacity of 90% or the highest based on Dale's experience cone. Training kits with simulator units and component units can facilitate basic learning up to the final or advanced stage of learning. The availability of jobsheets and learning modules that are suitable for training kits provides a seamless experience and understanding. The availability of training kits, job sheets, guidebooks, and learning modules as a result of development is in accordance with the opinion of [46] that competencies or skills must be mastered gradually and in stages according to Bloom's taxonomy

The results of the feasibility test in this study can be seen in Figure 4. The results of the feasibility test come from several aspects developed, including material/content aspects, utility aspects, appearance aspects, and technical/operational aspects. Based on the results of the feasibility tests that have been carried out, it can be concluded that the training kit developed is very feasible for use in the learning process of the control system. Expert validation of product feasibility obtained an average percentage of 95.5% in the very feasible category. User responses by teachers gave an average percentage of 95.5% in the very feasible category. The average percentage of 90.8% was obtained from user responses by alumni and students.



(a) (b) (c)

Figure 4. (a) Expert Validation Results; (b) User Assessment Results by Teachers; and (c) User Assessment Results by Graduates

Testing the effectiveness of the training kit in this study uses a quasi-experiment with a pretest-posttest control group design model. Hypothesis testing uses the Paired Sample t-test. The test results obtained a sig value (2-tailed) (0.000) < 0.05, then H_0 was rejected, and H_a was accepted. Based on the decision of the test criteria, it can be concluded that the use of training kits has a significant (effective) influence on student learning outcomes.

Testing the difference in learning outcomes using a training kit and without using a training kit to find out if there is a significant difference. Hypothesis testing uses the Independent Sample t-Test. The test results obtained a sig value (2-tailed) (0.000) < 0.05, then H_0 was rejected, and H_a was accepted. The test results also obtained data that calculated (5,912) > table (1,998), then H0 was rejected, and H_a was accepted. Based on the decision of the test criteria, it can be concluded that there is a significant difference between the learning outcomes of students who use and those who do not use the training kit. The results of the N-Gain test can also be concluded that the application of treatment in the form of the use of training kits has high effectiveness. The N-gain value of the experimental class of 0.77 was higher than that of the control class of 0.62, as shown in Figure 5.

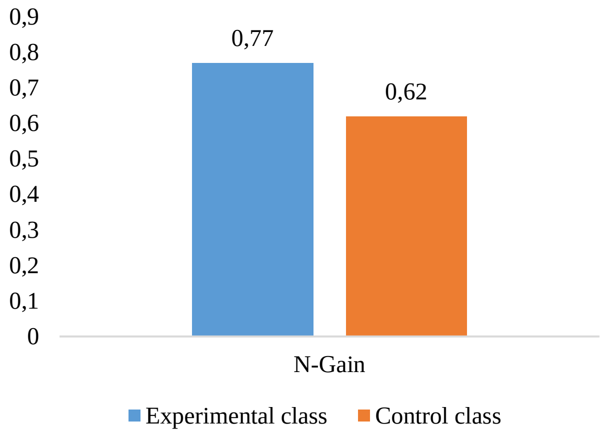


Figure 5. N-Gain Test Results

The results of testing the effectiveness of the training kit are in accordance with [23] that the right learning media can improve the quality of learning. The results of the effectiveness test in this study are in accordance with [17] that learning media is an important part of supporting learning. Teachers can explain the concept and application of learning materials easily. The availability of training kits can increase activities, motivation and stimulation of learning in students [10].

CONCLUSION

The results of research and product development are in the form of training kits equipped with jobsheets and manuals. The training kit is made in 2 units, namely the component board and the simulator board. The training kit has electro-mechanical, PLC, VFD/Inverter, Smart Building and IoT-based control coverage. The scope of control system competencies includes planning, preparation, installation, operation, evaluation and troubleshooting.

The training kit developed is considered very worthy of review in terms of material/content, usefulness, appearance and technical/operational. Expert validation of product feasibility obtained an average percentage of 95.5% in the very feasible category. User responses by teachers gave an average percentage of 95.5% in the very feasible category. The average percentage of 90.8% was obtained from user responses by alumni and students.

Training kits have a significant influence and difference on student learning outcomes based on t-test results. The results of the N-Gain test can be concluded that the application of treatment in the form of the use of training kits has high effectiveness, with a value of 0.77 in the experimental class and 0.62 in the control class.

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