Development of a Control System Trainer using AVR Microcontroller to Understand Microcontroller Programming Concepts

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ABSTRACT
Microprocessor and Microcontroller are subjects that must be taken by Industrial Electronics Engineering students at Kepanjen 1 Vocational High School in semester 4 and semester 5. Through observation it is found that TEI expertise competencies do not yet have trainers who are devoted to simple control system learning. The lack of learning media can be overcome by developing trainers to make it easier for students to understand the concept of microcontroller programming using C language and create a simple application program for system controllers with microcontrollers. The model used for this development is the ADDIE development model. The steps that are carried out are: Analyze, Design, Develop, Implement, and Evaluate. Development of learning media has gone through an expert validation process with a percentage of 93.96% (very valid) by experts 1, 93.96% (very valid) by experts 2, and 95.68% (very valid) by expert 3, trial of the product twice by students with a percentage of 88.8% (very valid) in small group trials and 92.63% (very valid) in field trials, then implemented to students and obtain an average score of 84.5.

Keywords: *Learning Media, Trainer, Control System, Programming, Microcontroller.*

1. INTRODUCTION

Education is a conscious and planned effort to create a learning atmosphere and learning process so that students actively develop their potential to have religious spiritual strength, self-control, personality, intelligence, noble character, and the skills needed by themselves, society, nation and state [1]. In everyday life humans cannot be separated from the elements of education, both formal education such as academic learning in schools and non-formal education such as social learning in the home environment. If humans live without education, this will create generations that are difficult to develop and even underdeveloped. Therefore, to produce quality human resources (HR) and have competitiveness, the implementation of education must also be of high quality and be carried out as well as possible.

Indonesia's industrial world needs around 600 thousand workers in a year, but the number of competent workers with vocational high school graduates is apparently not comparable to the needs of the world of work [2]. Improving the quality and competence of Vocational High Schools is urgently needed, because then Vocational High School graduates will be more competent in their fields and ready to enter the industrial world in Indonesia. To produce quality human resources, of course, the learning process in Vocational Schools must be designed in such a way as to help students get to know technological developments in this global era.

Teaching methods and learning media are the two most prominent aspects of learning methodology [3]. A teacher must be able to explain and use the available learning tools. The learning media used must of course be in accordance with the characteristics of the students and their learning objectives. Teaching aids are learning aid media, and all kinds of objects used to demonstrate subject matter [4]. Trainers are intended to support student learning in applying knowledge/concepts obtained to real objects. The function of learning media in vocational education is critical since, in essence, vocational education focuses on the competence of skills, which necessitates learning media intellectually and practical ways that may accommodate learning [5].

There are some studies about developing learning media using microcontroller or microprocessor. The uniform circular motion learning media based on Arduino Uno has been developed using Research and

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Development (R&D) method based on the 4D model [6]. Wahyudi et.al has developed microcontroller-based robotics trainers as learning media [7]. A study was done to design and construct solar system learning medium for elementary school pupils [8]. This learning media is not developed for microcontroller learning but it is developed for another subject.

There are some studies about developing learning media using microcontroller or microprocessor learning. An Internet of Things (IoT) laboratory work learning media has been developed using NodeMCU [9]. This learning media is developed for learning IoT. Industry based microprocessor learning module has been developed [10]. A microcontroller learning media has been developed by using STM32 ARM Cortex-M [11]. An analog and digital trainer has also developed based on Arduino [12], [13]. However, these four-learning media is specialized for undergraduate student. The learning media in this study is developed for Vocational High School (VHS) student. Therefore, those learning media is not suitable.

The learning media is developed VHS. The study is take place on State Vocational High School 1 Kepanjen (Sekolah Menengah Kejuruan Negeri/SMKN 1 Kepanjen). Through an interview that was conducted with one of the teachers, it was found that this school has learning media in the form of a microcontroller trainer but does not yet cover all existing basic competencies. The available trainer uses the Atmel 89S51 microcontroller. The first drawback of this trainer is that the language used for programming still uses assembly language, where to write a complex program it will require long lines and need a long time to write. Second, this trainer is still a separate component and requires more time to assemble it before starting the practicum. Trainers specifically used for learning simple control systems are not currently available.

Based on the explanation above, the researchers developed learning media in the form of trainers to make it easier for students to understand the concept of microcontroller programming using C language and create simple application programs for controlling systems with microcontrollers on Microprocessors and Microcontrollers subjects. In addition to making, it easier for students to understand the concept of microcontroller programming and create simple control systems, this trainer is also practical in use and comes with a user manual.

2. METHOD

The development model used for the development of a microcontroller-based control system trainer uses the ADDIE development model. The choice of the ADDIE development model is due to the following reasons: (1) it can be used for media development; (2) the development model is flexible; (3) allows evaluation at every step of its development; (4) the final product does not have to be mass produced [14].

Based on the ADDIE development model [15], the development stage in this study consisted of 5 steps, namely: (1) analysis of the needs of microprocessor and microcontroller learning media; (2) design of instructional media in the form of trainers and jobsheets for practicum control systems based on microcontrollers; (3) development of trainers and practicum jobsheets for microcontroller-based control systems; (4) implementation of trainers and practicum worksheets for microcontroller-based control systems; (5) Evaluation.

2.1. Analysis

The steps taken at this analysis stage were through observation and interviews with the teachers. From the results of observations and interviews that have been conducted, it can be concluded that: (1) The curriculum used in the 2017-2018 school year is different for each class, namely: class X uses the 2013 Revised 2017 Curriculum, class XI uses the 2013 Curriculum, and class XII uses the 2013 Curriculum Education Unit Level (KTSP); (2) Microprocessor and Microcontroller subjects have basic competencies in making control system application programs with microcontrollers; (3) The learning media used are trainers, job sheets, and modules; (4) The microcontroller trainer used uses an Atmel 89S51 which is separate from input and output practice components; (5) Input and output components in the form of push buttons, toggle switches, light emitting diodes (LEDs), and liquid crystal displays (LCD) 16x2; (6) The language used for programming uses assembly language; (7) Special trainers for learning control systems using microcontrollers are currently not available.

From the results of the needs analysis carried out, it can be concluded that special learning media are needed to discuss the control system. The learning media must also be practical in its use in order to minimize component damage due to assembly errors and be more efficient in the learning process.

2.2. Design

The products developed are in the form of trainers and job sheets. The developed worksheet will discuss several materials, namely: (1) DC motor control with a temperature sensor; (2) stepper motor control with ultrasonic sensors; (3) control of servo motors with LDR sensors. The main control of the trainer uses ATMega16. The trainer is fixed or in other words cannot be disassembled using a banana jack connector as a link between parts.

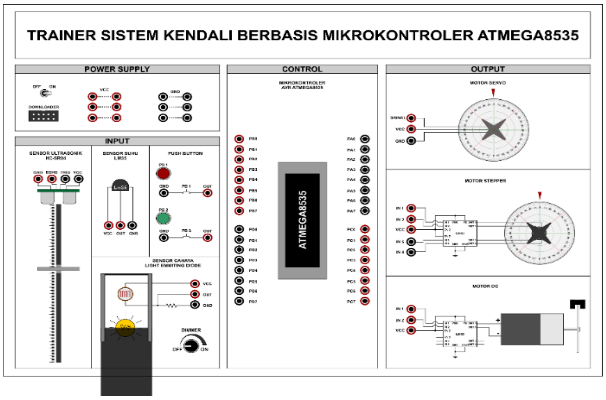

Figure 1 The Design of the AVR Microcontroller Based Control System Trainer

This trainer has 4 main parts, namely: (1) power supply; (2) inputs; (3) controls; and (4) outputs. This AVR Microcontroller Control System Jobsheet format contains: (1) title; (2) practicum objectives; (3) material description; (4) tools and materials; (5) occupational health and safety; (6) work steps; (7) practicum assignments; (8) practicum results; (9) evaluation; (10) answer. The material design to be presented on this jobsheet refers to the basic competencies for the Microprocessor and Microcontroller subject, namely creating a microcontroller control system application program.

2.3. Development

At the development stage, the activities carried out are realizing the design that has been designed into a ready-to-use product. The stages for making a product in the form of a Control System Trainer with AVR Microcontroller begin with preparing the tools and materials used in accordance with the planned design, purchasing trainer tools and materials, printing trainer layouts, and installing trainer components, then installing cables on components that have been installed and modification of the trainer if there are deficiencies during manufacture.

2.4. Implementation

The implementation is conducted by doing trial stage. The first trial phase is to conduct a one-to-one trial or validation with experts. Validation aims to determine the validity or feasibility of the product that has been made. Besides that, this trial is intended to get comments from experts about the product being developed. The expert in this study were 2 lecturers of Electrical Engineering, State University of Malang and 1 teacher at SMKN 1 Kepanjen.

The trial is then followed by a small group trial. The purpose of this small group trial is to identify product deficiencies after revision based on individual trials. Students who were taken as test subjects at this stage were a total of 10 people.

After the product was revised based on input at the small group trial stage, the product was then tested at the field trial stage. The purpose of this field trial is to identify the deficiencies of the product when used under conditions similar to actual conditions. Students who were taken as field trial subjects were a total of 22 people.

2.5. Evaluation

After each completion of the trial phase, data will be obtained from the assessment results of the trial subjects. The data is used to determine the feasibility level of the product being made. If the data from the results of the assessment states that the product is not feasible, improvements will be made according to the input of the test subjects on the product being developed.

The number of XII TE1 students at SMKN 1 Kepanjen is 108 students, with details of 37 students in class XII EI 1, 34 students in class XII EI 2, 37 students in class XII EI 3. Several students were taken as samples using a random sampling technique. Based on calculations using the slovin formula, the results obtained were 51 students of class XI TEI at SMKN 1 Kepanjen as test subject students.

The types of data obtained from the trial phase are qualitative and quantitative data. This data was obtained from a questionnaire given to the trial subjects. The instrument in the form of a questionnaire was arranged based on a grid according to Arsyad [4], Wena [16], and Wahono [17]. Field trials were carried out by taking data from 22 students. The instrument in the form of a questionnaire was arranged based on a grid according to Arsyad [4], Wena [16], and Wahono [17].

In the data analysis process, the products that have been produced will be validated by experts and students. The validation aims to measure the validity or feasibility of learning media before being field tested using an instrument in the form of a questionnaire.

3. RESULT AND DISCUSSION

The results of product development for the Microprocessor and Microcontroller subject in the basic competencies of making simple application programs for controlling systems with microcontrollers are in the form of AVR Microcontroller-Based Control System Trainers and jobsheets. The following is an explanation of each product:

3. 1. AVR Microcontroller Based Control System Trainer

The interface uses wood as the trainer frame and 2 acrylic pieces has the following functions:

a. The upper acrylic is used as a socket installation place and covered with stickers to provide information on the power supply, input, control, output, trainer identity, and display sections.

b. The bottom acrylic is used as a cover for the electric trainer circuit.

Figure 2 Dimensions of the AVR Microcontroller Based Control System Trainer

The dimensions of the trainer being developed are 41.5 cm x 33 cm x 4.5 cm. For more details, the dimensions of the AVR Microcontroller-Based Control System Trainer are presented in Figure 2. Each part of the trainer is explained as follows:

a. Power supply, In the power supply section, there are (1) switches that function to turn on and turn off the trainer; (2) downloader port to enter the program into the microcontroller; (3) 4 sockets +5V, 2 sockets +12V and 6 ground sockets as trainer voltage sources.
b. Inputs, At the input section there are (1) HC-SR04 ultrasonic sensor to measure changes in the distance of objects equipped with 4 sockets and a meter to measure the distance of reflected objects; (2) LM35 temperature sensor to read changes in temperature equipped with 3 sockets (3) LDR (Light Dependent Resistor) sensors to read changes in light intensity equipped with 3 sockets; (4) LED dimmer to adjust the light intensity of the lamp.
c. Control, In this section there is an ATMega16 AVR microcontroller which functions as a circuit controller on the trainer. The number of I/O sockets in this control section is 24 sockets, namely in (1) port A there are 8 sockets; (2) port C has 8 sockets; (3) port D has 8 sockets; (4) port B does not use a socket because it is connected internally with a 16x2 LCD.
d. Output, At the output there are (1) the MG90S servo motor equipped with 3 sockets; (2) 28BYJ-48 5V stepper motor driven by ULN2003 equipped with 6 sockets; (3) Direct Current (DC) motor driven by L298N equipped with 6 sockets.
e. Trainer identity, In the trainer identity section, there are (1) the name of the trainer; (2) the identity of the trainer maker.
f. Displays, in this section there is a 16x2 LCD which is internally connected to the microcontroller.
g. Trainer voltage source, At the top of the trainer there is a DC socket which is connected to a 12V DC adapter to provide voltage to all parts of the trainer. A Buck converter DC to DC L2596 is used reduce the 12V voltage to 5V as a voltage source for sensors and motors in the trainer

3. 2. Validation Result

3.2.1 Expert Validation Result

The validation test or review was carried out by 2 lecturers from the Department of Electrical Engineering, State University of Malang, and by the teacher of the Microprocessor and Microcontroller subject at SMKN 1 Kepanjen. The review was carried out to obtain quantitative data from filling out the questionnaire and qualitative data in the form of criticism and suggestions. The questionnaire instrument was compiled based on the learning media assessment grid according to Arsyad [4], Wena [16], and Wahono [17]. The validation result is shown on the Table 1.

The average rating score is 93.96% for expert 1 (E1), 93.96% for expert 2 (E2), and 95.68% for expert 3 (E3). The qualitative data obtained are as follows:

a. LM35 sensor pins should be given a capacitor.
b. The LDR sensor should be mounted on the PCB.
c. The power supply used should produce a stable voltage and greater current.
d. Rulers and bounce objects should be packed together with the trainer.

Table 1. The validation results.

#	Assessment Aspects	Total Expected Score	Total Empirical Score			Percentage (%)		
			E1	E2	E3	E1	E2	E3
1	Content Eligibility	20	19	20	20	95.00	100.00	100.00
2	Completeness	36	36	34	34	100.00	94.44	94.44
3	Presentation	24	22	24	23	91.66	100.00	95.83
4	Technical Quality	36	32	31	34	88.88	86.11	94.44
Total		116	109	109	111			
Average						93.96	93.96	95.68

e. Reflective objects should be added to the list of tools and materials on jobsheet 3.
f. The display of the 2nd line of the LCD on Jobsheet 2, part of Practicum Assignment C, should be removed.
g. The command to shift the bouncing object is added to the Jobsheet 3 Work Steps section.

The results of the percentage validation of each expert, all three are in the very feasible category. Products in the form of AVR Microcontroller-Based Control System Trainers and Jobsheets for the Microprocessor and Microcontroller subject of the class XI Industrial Electronics Engineering expertise program were declared suitable for use in learning.

Based on the suggestions from the results of the validation of experts, it is necessary to revise the product made. Product revision is carried out to improve the product that has been produced before the product is tested on students.

3.2.2. Product Trial Result Data

The data from the small group trials is shown in Table 2, while the data from the field trials is shown in Table 3. Overall, the percentage results from small group trials were 88.8% and from field trials of 92.63%. The results of the percentage of small group trials and field trials fall into the very feasible category. Products in the form of AVR Microcontroller-Based Control System Trainers and Jobsheets for the Microprocessor and Microcontroller subject of the class XI Industrial Electronics Engineering expertise program were declared suitable for use in learning.

Table 2. The Small Group Trials Results

#	Assessment Aspects	Total Expected Score	Total Empirical Score	Percentage (%)
1	Completeness	360	323	89.72
2	Presentation	240	213	88.75
3	Technical Quality	400	352	88.00
Total		1000	888	
Average				88.80

Table 3. The Field Trials Results

#	Assessment Aspects	Total Expected Score	Total Empirical Score	Percentage (%)
1	Completeness	792	736	92.92
2	Presentation	528	489	92.61
3	Technical Quality	880	813	92.38
Total		2200	2038	
Average				92.63

3.2.3. Product Implementation Results

The implementation was carried out to 20 class XI students of the Industrial Electronics Engineering Expertise Program at SMKN 1 Kepanjen who had studied the basic theory of microcontrollers, the concepts of microcontroller programming and control systems. Implementation of AVR Microcontroller-Based Control System Trainers and Jobsheets is carried out through practicum to measure the level of understanding of students' programming concepts. The practicum is carried out by discussing Jobsheet 1: DC Motor Control with an LM35 Temperature Sensor. The practicum was held on Friday January 25 2019 in class XII TEI 1 which was accompanied by 4 students from the UM Electrical Engineering Department as observers. Each observer observed 5 students.

Table 4. The Cumulative Data on Knowledge Aspect

#	Assessment Aspects	Max Score	Score Obtained	Final Score
1	I/O configuration	80	72	90
2	Variable Declaration	80	65	81.25
3	Reads LM35 temperature sensor data	80	68	85
4	Controls the speed and direction of rotation of the DC motor	80	70	87.5
5	Controls DC motor speed with a temperature sensor interface	80	63	78.75
Total		400	338	

Practicum is carried out by dividing students into 4 groups with each group containing 5 people. Each group was assigned to work on Jobsheet 1 and observers conducted question and answer sessions with students during the practical activities. Groups that have finished working on practicum assignments are welcome to upload the program that has been made to the trainer. After completing the assignments and practicum evaluation students submit worksheets to the observer. The cumulative data on knowledge aspect is shown in Table 4.

The level of students' understanding is taken based on the assessment of the aspect of knowledge through observation. Based on Table 4 it can be seen that the average of the learning outcomes of students participating in learning is 84.5. The average student learning outcomes are above the Minimum Completeness Criteria, namely 75. Based on student learning outcomes it can be concluded that the product in the form of AVR Microcontroller-Based Control System Trainers and Jobsheets for Microprocessors and Microcontroller Subjects, the Industrial Electronics

Engineering Expertise Program can be used as a way to understand the concept of microcontroller programming to students.

4. CONCLUSION

The development of learning media that has been carried out using the ADDIE Development Model has gone through a process of expert validation, product trials by students, and implemented to students. The product developed is in accordance with the development objectives that were previously prepared. The AVR Microcontroller-Based Control System Trainer has been successfully developed for use in Microprocessor and Microcontroller subjects. The AVR Microcontroller Based Control System Jobsheet has been successfully developed to be used as teaching material in learning activities. The products that have been made have gone through validation tests by experts with results that fall into the very valid category from each expert. The product was also tried out by students 2 times with results that were in the very valid category from each trial that had been carried out. Products made have been implemented in student learning activities and get an average value of 84.5. These results are above the KKM (Minimum Completeness Criteria) which is equal to 75, so the AVR microcontroller-based control system jobsheet and trainer can be used as a medium to understand the concept of microcontroller programming to students.

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