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Implementing Three-Phase Trainer to Improve System Programming Learning at Vocational High School (VHS)

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***Abstract*— The use of programming languages in microcontroller programming is very influential on student learning outcomes. The use of C language, which is easier to understand, should be taught to the students to improve their programming skills. This study aimed at improving student learning outcomes, especially their microcontroller programming skills. Borg & Gall method was used in the study in which it had been adapted based on the needs of the study. The results of the research showed that the product developed using C language was effectively applied as learning media. The product can improve not only the students' skills, but also the students' knowledge aspect.**

Keywords: three-phase motor, trainer, microcontroller programming, C language, programming competence

I. INTRODUCTION

A trainer is a simulation process using a model of real objects to describe a behavior of a system. In the education world, trainer has a function to explain the complicated theory accepted by students. In addition, the trainer can be used as a medium to improve student skills. In the automation system programming subject, the trainer has a role as a medium to train the students to improve their abilities in programming microcontroller.

Automation system is a system which working mechanism is controlled by electronic equipment based on commands in the form of software programs stored in electronic controller memory units. The automation system has functions to manage and control the output score so that it will meet the expectation. The controlled equipment is called an output, the equipment that manages and controls is called a controller, and the equipment that gives commands is called an input.

A three-phase automation system motor trainer has inputs in the form of 3 normally open push buttons by using the ATmega16 microcontroller as the controllers. Whereas the three-phase motor acts as an output system that should be controlled. The microcontroller cannot give direct commands to the three-phase motor due to the electric potential difference in these two components. A Microcontroller based DC voltage has an output voltage of 5 Volts, while a three-phase motor is running with 380 VAC. Thus, it is necessary to add some supporting components as the connectors, relay and magnetic contactors.

Microcontroller programming cannot be separated from the use of programming languages. In general, programming languages are classified into three levels, low, middle, and high-level languages. The classification of the programming languages is adjusted to the construction of the language used.

Assembly programming language is classified into a low-level programming language as the construction of the language uses machine language. It is a basic programming language taught to students at vocational school level.

Another programming language that can be taught to the students as a basis for microcontroller programming is C Language. It is a mid-level programming language whose language construction is easier to understand than the Assembly language. It is known that the C language is often used in microcontroller programming competitions at the vocational level, but, in fact, it is rarely taught to the students.

High-level programming language like Pascal cannot be used as microcontroller programming language due to the limited features found in the microcontroller. The high-level programming language is generally used as programming language for an interface such as using Delphi.

Based on the explanations, the use of programming language is closely related to students' ability in programming microcontrollers to control three-phase motor. The observation results conducted in SMK Negeri 1 Kepanjen showed that the students had difficulty in understanding the Assembly programming language; hence, the average score of the students' skills is still below the standard. To solve the problem, implementing a three-phase motor trainer for learning of automation

system programming using the C programming language is highly needed.

The learning implementation is closely related to the learning model used, Project-based Learning; it is to improve learning activities and student learning interest.

To support the research process, several observations from relevant researches had been conducted; (a) developing a learning of 3-phase induction motor control trainer based on smart relay to operate 3-phase motor as the production machine, (b) developing industrial control trainer based on PLC Omron CP1L-40 I/O to control industrial machines (induction motor), (c) developing conventional relay teaching material as the learning media during class practicum, and (d) designing Automatic Transfer Switch by using magnetic contractor as the controller. Meanwhile, this study emphasizes more on the use of ATmega16 microcontroller to control magnetic contactors, relays, and 3-phase induction motor, especially on the competency of the electronic control system programming related to the microprocessor and microcontroller-assisted I / O access.

The limitation of the study is focusing only on the effect of the implementation of the trainer using the C language to improve three aspects –knowledge, attitude, and skill– of the students based on the Curriculum 2013.

II. RESEARCH METHOD

Borg & Gall method was used in this study consisting of (1) research and information collecting, (2) planning, (3) developing preliminary form of product, (4) preliminary field testing, (5) main product revision, (6) main field testing, (7) operational product revision, (8) operational field testing, (9) final product revision, dan (10) dissemination and implementation [8].

A. Research and Information Collecting

Preliminary study was needed to strengthen the information in which it consisted of 3 stages, namely (a) needs analysis, (b) literature review, and (c) small-scale research. Based on the results of the research and information collecting, it was very needed to develop a trainer equipped with a workbook and a manual book as the media to improve the student skills. The results of an interview to a subject teacher, Mr. Agus Nurhadi, showed that the average score of students' knowledge was above the minimum criteria of mastery learning (KKM); on the other hand, the average score of students' skill was still below the KKM. Then, the questionnaires were distributed to 60 students of XII EI grades in order to get more data. The results showed that 67% of the students stated that it was necessary to develop trainer because of the difficulty of using Assembly language.

B. Planning

There were four references used in the planning steps, namely (a) the purpose of product use, (b) the subjects of the product user, (c) the time and location of the product trial, and (d) the description of the components used as product builder. The main purpose of the product use was as a medium to increase the average score of the students' skills. The product would be used by 110 students of XII EI grades who were accompanied by 3 teachers and a toolman as a product maintenance officer. The entire trial process was conducted on even semester 2017/2018 at SMK Negeri 1 Kepanjen, Malang. While the components of the product were all consumables used to compile the trainer, the workbook, and the manual book.

C. Developing Preliminary Form of Product

Product was a stage of realization towards research stages, data collection, and planning steps that had been conducted in the previous steps. In this stage, evaluation process of a rough finished product was carried out. The evaluation process was validated by the advisors and the subject teacher. It aimed at testing the feasibility level of the product before being tested in the school. The validation test consisted of trainer validation and workbook validation. The validation of the trainer covered 5 aspects, (a) suitability, (b) security, (c) quality, (d) benefit, and (e) appearance. While the validation of the workbook consisted of 6 aspects, (a) content, (b) presentation, (c) language, (d) student-oriented, (e) benefit, and (f) appearance.

D. Preliminary Field Testing

Preliminary field testing was an initial field trial to the students. The trial was conducted in class to make the students work efficiently based on the actual situation and condition. The purpose of the trial was to determine the feasibility level of the product carried out by 6 students of XII EI grade.

E. Main Product Revision

The first revision was carried out based on the suggestions and comments given in the initial field testing. The product revision was done to prepare the product well before being tried at the main field testing.

F. Main Field Testing

Main field testing was tried to 34 students XII EI-2 grade to determine the feasibility level of the product. This trial was conducted using more samples as the product produced was the standard product for XIIth grade. Thus, the number of the samples must represent the entire class of XIIth graders.

G. Operational Product Revision

The revision of the operational product was the stage of product improvement. The revision was carried out based on the suggestions and comments given during the main field testing. The improvements were done to prepare better product for operational field testing.

H. Operational Field Testing

Operational Field Testing was used to test validity and effectiveness of the product and determine the strengths of it compared to the old product. The operational field testing was conducted on 44 students who were divided equally into a control group and an experimental group.

The control and the experimental groups were group testing which had same characteristics and abilities, but

different treatment. The control group was treated using a product provided by the school, while the experimental group was treated using the product development of this study.

I. Final Product Revision

Final product revision was conducted to revise the product weaknesses based on the suggestions and comments in the operational field testing stage. In addition, this improvement was carried out to prepare the final product before being formally implemented in schools. This stage had been prepared carefully as any learning media that have been passed the operational product revision will be regarded as the perfect one.

J. Dissemination and Implementation

Dissemination and implementation were carried out after the final product in the form of the trainer equipped with the workbook and the manual book had been revised. The dissemination was a socializing stage in the form of a thesis report. The implementation was an application stage of the product at SMK Negeri 1 Kepanjen as a practicum media.

III. IMPLEMENTATION

The significant difference of the pre-test results between the experimental group and the control group was the initial ability of the test groups; it was on the effects of the trainer and the programming language used in the subject matter of 3-phase motor control using a microcontroller. Then, the significant difference between the post-test results of the experimental group and the control groups was on the effects of the trainer on students' knowledge aspect. Therefore, the significant difference between the scores in the pre-test and post-test and performance results was the improvement of the learning outcomes.

The significant analysis used t-test with two samples as in Equation (1). The t-test was used as it can compare two values of t-score and t-table. If the value of the t-score is higher than the t-table, it means that the comparison is significant. Then, correlation can be positive or negative. Positive correlation indicates a parallel relationship in the data being compared, while negative correlation indicates an inverse relationship to the data being compared.

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s1^2}{n_1} + \frac{s2^2}{n_2} - 2r\left(\frac{s1}{\sqrt{n1}}\right)\left(\frac{s2}{\sqrt{n2}}\right)}} \quad (1)$$

IV. RESULT

After a series of trials, the real form of the trainer product can be seen in Figure 1, and the trainer parts can be seen in Figure 2.

Figure 1. The real form of the trainer

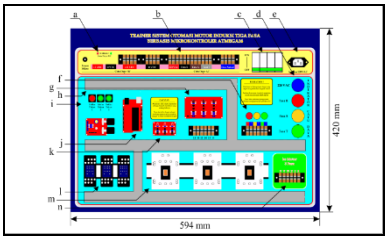

Figure 2. The parts of the trainer

The trainer had a length of 594 mm and a width of 420 mm with the arrangement: (a) DC power supply, (b) AC power supply, (c) miniature circuit breaker, (d) each phase indicator light (e) 220 Volt AC power supply input terminal, (f) 220 Volt AC lamp, (g) current amplifier circuit, (h) cable duct, (i) push button and sensor circuit, (j) ATmega16 minimum system circuit equipped with USBAsp, (k) LED circuit, (l) relay MY4N, (m) S-N21 magnetic contactor, and (n) output terminal to a 3-phase motor.

The products developed were not only the trainer, but also the workbook and the manual book which can be seen in Figure 3 and Figure 4.

Figure 3. The appearance of the workbooks

The different basic colors of the workbooks for the students and the teacher are green and yellow, respectively. However, both books have same contents consisting of (a) table of contents, (b) practical objectives, (c) short theory, (d) occupational health and safety, (e) tools and materials, (f) circuit drawings, (g) program listing, (h) practicum procedures, (i) practicum results, (j) analysis of practicum results, and (k) independent assignments.

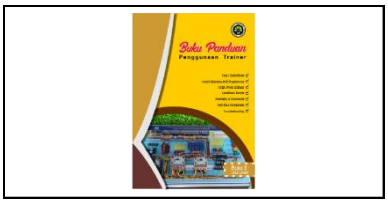

Figure 4. The appearance of the manual book

The manual book includes (a) occupational health and safety, (b) descriptions of trainer parts, (c) procedures of trainer use, and (d) analysis of trainer damage.

Analysis Results of Significance Test can be seen in Table 1 and Table 2.

Table 1. Analysis Results of Significance Test of Experimental and Control Groups

	Average		r_{ek}	*t* Value		Criteria of Significance
	Exp	Control		Table	Score	
Results of *Pretest*	60,682	60,636	0,059	2,086	0,015	Insignificant
Results of *Posttest*	83,030	75,152	0,344	2,086	2,265	Significant
Results of *Performance*	83,401	74,838	0,199	2,086	4,200	Significant

Information:
- Exp : Experimental group
- r_{ek} : Correlation between experimental and control groups

Table 2. Analysis Results of Significance Test of Post-test and Pre-test Results

Groups	Average		r_{pp}	*t* Value		Criteria of Significance
	Post	*Pre*		Table	Score	
Experimental	83,030	60,682	0,597	2,086	9,441	Significant
Control	75,152	60,636	0,562	2,086	5,430	Significant

Information:
- Post : Results of post-test
- Pre : Results of pre-test
- r_{pp} : Correlation between results of post-test and pre-test

Table 1 showed that the learning outcome of the experimental group was higher than the control group's. The difference of the average score in pre-test results between the experimental group and the small control group was 0.046 in which it showed that both groups had same abilities. However, after being treated using the C language, the experimental group showed better improvement than the control group. This was proved by significant difference between the average post-test score of the experimental group and the control group which was 7.878, and the difference in the average achievement of performance was 8.563 where the performance of the experimental group was higher than the control group.

Table 2 showed that the learning activities using old product and product development showed a significant increase in learning outcomes. However, it should be noted that the learning activity using the product development showed higher learning outcomes than the old product. It showed that the improvements in learning outcomes by using the old product and the product development were 14.516 and 22.334, respectively.

V. CONCLUSION

Based on the results of study, it is known that the products developed are more effectively used as the learning media. The results show significant increase in the students' skills of 7.832 points higher than the old products. Moreover, the use of C programming language is easy to understand by the students. Finally, the evidence of the higher improvement of the experimental group than the control group can be seen in the post-test results and performance.

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