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Implementation of Simulation Software on Vocational High School Students in Programming and Arduino Microcontroller Subject

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Abstract: The purpose of this study is to determine students' learning performance who underwent simulation software class on the Programming and Arduino Microcontroller Subject. A quasi-experimental study, with pretest and posttest design was implemented. The subject involved 74 vocational high school students (37 in the control group and 37 in the experimental group) have undergone eight weeks of treatment, using conventional and Proteus simulation software. Students' performance was measured using achievement test; involved cognitive, psychomotor, and affective aspect, which was based on the Bloom's Taxonomy. The result indicated that students in the experimental group have outperformed their counterpart in the control group in cognitive aspect (81.4 vs 76.24), affective aspect (81.83 vs 76.34) and psychomotor aspect (79.04 vs 70.37). Further analysis using independent t-test, result indicated that the experimental group's performance has significantly difference from the control group's performance at all aspects [$t(72) = 3.068$, $p = .004$]. In conclusion, simulation software using Proteus has a significant contribution to increase students' performance in learning. The implication is that, teaching difficult subject involves programming of microcontroller should use simulation software, so that students become more enthusiast, have many choices in experimenting and capable of nurturing creativity. Future study suggested to focus on the effect of simulation software on nurturing specific creativity skills.

Keywords: Proteus, simulation software, programming, microcontroller, vocational high school, students' learning domains

1. Introduction

In Indonesia, Vocational High Schools are in great demand because of the learning process that provides training in various fields of expertise, especially in technology and vocational. The prominent roles of Vocational High Schools is to train students to be able to carry out certain types of duty and task in the respected occupational field (Fajra & Novalinda, 2020; Rosina et al., 2021), and being the reason why vocational training is deemed important in this training institution (Ana, 2020; Handayani et al., 2020a; Handayani et al., 2020b; Hidayat et al., 2020; Nandiyanto et al., 2020a). Thus, Vocational High Schools plays a significant role to bridge the gaps of students' competency training in the vocational institution and the needs of the industry.

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In Vocational High Schools, an interaction between students and their learning environment to achieve the learning goal, being a common practice in the learning process that is regulated by teachers. Interaction is very important in this case (Lumbu-ani et al., 2021), particularly, to provide a good understanding on the material and content, and thus maximum results of training can be achieved (Hanif, Wijaya, & Winarto, 2019). Besides, instructional learning media serves as an important element to achieve at students intended competency level, but not merely to deliver the content of teaching materials, but also to increase students' enthusiasm in learning (Budi, Kaprawi, Yunos, 2010). There are various instructional media available for teachers (Emy & Morbo, 2021; Sangsawang, 2020; Winarni & Rasiban, 2021; Glorifica, 2021; Huwaidi, Nandiyanto, & Muhammad, 2021; Kasmana et al., 2021; Nandiyanto et al., 2020b; Hernawati & Nandiyanto, 2021), including the one that using a computer-supported media. Computer-supported media is based on computer-based technology, that is useful in designing and producing, as well as delivering learning materials in a digital system-based sources (Riza et al., 2019). Instruction can be creatively designed to entice students in learning and improve their knowledge and skills, including creativity (Liu et al., 2011). Also, it can solve learning issues and improve students' learning patterns and pace to be more effective by the adoption of new technology. Most importantly is that the instruction should be able to stimulate learning and reach at the higher level of cognitive, psychomotor, and affective.

Based on the observation, the learning process in a technical subject, such as programming and Arduino microcontrollers subjects have been done without utilizing instructional media to support the learning process. Programming-related subjects are one of the most challenging and are deemed difficult subjects for students at this level. The need of using computer media is deemed necessary, especially in teaching programming and microcontroller subjects, that require teachers to have more samples in showing more logics combination and examples. Without multiple samples, students might have difficulties getting the skills such as debugging skills, modifying code, and observing their effects, and reaching students' understanding and high level of creativity. Learning might be difficult to reach a higher level of the taxonomy for cognitive, psychomotor, and affective. In this study, students' learning domains refers to the new Revised Bloom's Taxonomy that caters; cognitive, affective, and psychomotor (Forehand, 2010). The cognitive domain includes the ability to remembering, understanding, applying, analysing, evaluating, and creating. The affective domain includes a focus on students, receiving, responding, valuing, organizing and characterization by a value complex. The psychomotor domain focuses on the development of student's physical abilities and skills, comprises perception, set, guided response, mechanical response, complex response, and adaptation origination. In this study, one of the important contents of the subject is the need to design a circuit using computer-aided design software (Rifai et al., 2020). Proteus is one of the software to support the learning process of schematic drawing, designing PCB and simulation.

Teaching using Proteus Simulation Software in electric, electronic, and electrical teaching application analysis courses have received much concern from several previous studies with encouraging positive findings (Liu et al., 2011; Yilmaz Ince & Koc, 2021; Jumini et al., 2020). For instance, a study on the implementation of proteus based microcontroller multichannel temperature acquisition system simulation design from Yuan et al. (2007). Next, the study that was designed and simulates of an SMS driven microcontroller for home automation using proteus software from Olamide & Joshua (2012). The other study discussed the implementation of the digital control using Proteus VSM Software (Su & Wang, 2010; Mukherjee, Ray, & Das, 2014) and the design of a prepaid energy meter based on PROTEUS (Himawan, Suprianto, Thamrin, 2015).

Proteus software can improve the learning outcomes of students because some features in Proteus software will help the students to understand materials that have been delivered by the teacher (Sessink, 2007). Some researchers have proposed a booklet about the implementation of Proteus software for Technical Drawing subjects, containing a basic guide of drawing using Proteus software (Singh et al., 2016). From another report, Proteus software for microcontroller subjects has yielded a positive outcome; the application of Proteus software as an instructional media on students' learning outcomes reaches 81% successfulness. In addition, a collection of software simulations and material for teaching examples improved the capabilities of students to carry out computer control system design analysis. A study concluded that Proteus (as simulation and programming tool software) reduces the investment of laboratory cost and provide teachers and students aware of the current computer controller technology development (Kholis, Zuhrie, & Rahmadian, 2018). Nevertheless, previous research indicated scarcity of the study on the implementation of Proteus on programming using Arduino microcontroller. Therefore, the purpose of this study is to determine the effect of applying proteus software-based instructional media on students' learning domains (cognitive, affective, and psychomotor) in the programming and Arduino microcontroller subject.

2. Methodology

This research utilised an exploratory strategy with quasi-experimental (control and experimental group), pre-test and post-test design. This design using a control group can control the confounding variables that influence the treatment, such as characteristics of subjects, history, maturity, and instrumentation (Seltman, 2018). This plan is comparable with the pre-test and post-test control group plan with the purpose of deciding the comparable lesson. See Table 1.

Table 1 - Pre-test result

Select Control Class	Pre-test	Used Proteus software	Post-test
Select Experimental Class	Pre-test	Non-Proteus software	Post-test

2.1 Population and Sample of Research

The population that is used in this study was grade ten students in Telecommunication Transmission Engineering Department at Vocational High School in Bandung Raya, West Java who enrolled in programming and Arduino microcontroller subject. Random selection was not satisfied as this research is a quasi-experimental study using intact classes, but classes were randomly assigned to the control and experimental group. A total of 74 students were willing to attend the classes and participated in this study. From 74 students, it was divided into two groups, 37 students for each class, both control group class and experiment group class, were randomly assigned and were deemed homogeneous since students' demographic and characteristics were identical.

2.2 Treatment Procedure in Control and Experimental Group

In the control group, a teaching session was going on for a three-hour session using a conventional method, where students were given a lecture on the basic theories of microprocessor and microcontroller, then move to a practical session on the basic microprocessor and microcontroller programming. Next, students were demonstrating (sharing session) the basic programming using a sample of applications to the class. Then, the rest of the remaining time allocation is for students to explore their own creativity in creating various options of microprocessor and microcontroller (in this case, Arduino Uno) in a daily application or case study. This method was repeated for eight weeks parallel with the experimental group, taught by a similar teacher, and using a similar syllabus.

In the experimental group, a teaching session was going on for a three-hour session. The first 15 minutes was the introduction to the microcontroller, particularly in this case was using the Arduino Uno that was programmed using Proteus software. The next 30 minutes was for theory and demonstration of simulation. In the remaining two hours was allocated for the practical session, students were given ample time to complete their task in creating Arduino Uno microcontroller application projects. In the last 15 minutes was evaluation; students were asked to present and run their project and followed by a conclusion session. In this group, Proteus was used as application software for practising tools as an alternative way in creating various programming possibilities based on the Arduino Uno microcontroller. This class was repeated for eight weeks using different projects and modules.

2.3 Instrument

A total of 45 items were used to gauge students' performance in cognitive, psychomotor, and affective according to Bloom's taxonomy. In Part A (cognitive), 15 items were used to measure remembering, understanding, applying, analysing, evaluating, and creating. In Part B (psychomotor), 15 items were used to measure perception, set, guided response, mechanical response, complex response, and adaptation origination. In Part C, 15 items were used to measure receiving, responding, valuing, organising, Characterization by a value complex. Items were tested in a pilot test involving 30 students from another similar group, the result; one item was removed for cognitive, two items for psychomotor, and two items for affective, the remaining 40 items left for an actual study.

3. Results and Discussion

The majority of the students involved in both classes were male; in the control group (33 male, 4 female), in the experimental group (30 male, 7 female). It is common in Indonesia, technology and the vocational school recorded a small number of female students. (see Table 2).

Table 2 - Demographic information in control and experimental group

Gender	Experimental	Control
Male	30	33
Female	7	4

3.1 Pre-analysis

Data normality tests were conducted to measure the data distribution especially for the pre-test and post-test from both classes. A normal distribution is assumed when the test probability value is exceeding the two-tailed limit at 0.05. In this study, the results of the pre-test and post-test for an experimental group obtained probability values at 0.908 and

0.949. Meanwhile, in the pre-test and post-test data for the control group obtained probability values at 0.903 and 0.941. Therefore, the pre-test and post-test data in both classes are assumed to be normally distributed.

Homogeneity of variance test was also conducted on the pre-test to indicate the pre-condition of both experimental and control groups using Levene Test. The testing criteria of both samples are said to be homogeneous if the probability value exceed 0.05. In this study, the results of the homogeneity test obtained a significance value at 0.786, indicating that the pre-test data in the experimental and control group comes from a population with the same variance (Homogeneous), granted for further research. In other words, both groups were at similar performance before treatment.

The N-Gain calculation is used to determine the average improvement in student learning outcomes of experimental and control groups. Calculation [N-Gain] using statistical package for social sciences (SPSS). From the results of the calculation of normalized Gain in the experimental class of 0.5437. Since 0.3 < (0.5437) < 0.7, it can be concluded that the normalized Gain result includes moderate criteria. While the normalized Gain calculation results in the control class was obtained by 0.3426. Because 0.3 < (0.3426) < 0.7 so it indicated that the normalized gain result includes moderate criteria. As for the results of the calculation of N Gain, there is a difference in the normalized Gain value, or there is a difference in student learning outcomes between experimental classes using proteus and conventional control classes of 0.172. Although there is an increase in learning outcomes, but both are still in a moderate level. (see Table 3).

Table 3 - Pre-analysis result

Pre-analysis	Experimental	Control
Normality	0.908 (pre) 0.949 (post)	0.903 (pre) 0.941(post)
Homogeneity	0.786 (pre-test)	
N-gain	0.3 < (0.5437) < 0.7,	0.3 < (0.3426) < 0.7

N = 34 experimental; 34 control group

3.2 Students' Learning Performance in the Control and Experimental Group

The data of students' cognitive aspect was obtained by conducting pretest and posttest. The question are consist of 40 multiple choice questions and developed based on revised Bloom's Taxonomy (Forehand, 2010). The Indonesian curriculum more focuses on cognitive assessment. This is the main assessment of a student's achievements. The cognitive score of this research is shown in Table 2. The average score in the experiment group is 81.41 and the average score in the control group is 76.24. Interestingly, an insight into the cognitive aspect, creativity indicated a slightly increase. There was an increase 5.17 points (see Table 4).

Table 4 - Cognitive score

No	Criteria	Average Score in Control Group	Average score in Experiment Group
1.	Remembering	86.21	89.45
2.	Understanding	83.46	87.32
3.	Applying	78.37	86.61
4.	Analyzing	72.23	78.84
5.	Evaluating	69.51	73.94
6.	Creating	67.66	72.28
Total Average score in Affective Aspects		76.24	81.41

The highest increase in cognitive aspect was obtained on the criteria of applying (Dallyono, Sukyadi, & Hakim, 2020; Maryanti et al., 2021). It is understandable that with Proteus students has easy interaction, easy use and easy to apply from the examples (Budi, Kaprawi, Yunos, 2010). While the lowest increase score on the remembering criteria, both of the class got a high score. However, the value of the evaluation variable is still above the minimum graduation grade.

The data of the psychomotor aspect was obtained by observation during the learning process. The observation sheet has been developed based on Revised Bloom's Taxonomy (Forehand, 2010). The result can be seen in table 4. The average score in the experiment group is 79.37 and the average score in the control is 70.37. (see Table 5).

Table 5 - Psychomotor result

No	Criteria	Average Score in Control Group	Average Score in Experiment Group
1.	Perception	72.15	87.31

2.	Set	74.22	78.91
3.	Guided response	71.52	88.47
4.	Mechanical response	68.1	71.28
5.	Complex response	66.73	75.34
6.	Adaptation origination	69.48	72.9
Total of Average Score in Psychomotor		70.37	79.04

The highest increase results are obtained at Guided response criteria. With Proteus, students can conduct repeated experiments and very responsive the guide (Olamide & Joshua, 2012). While the lowest increase results are obtained on Complex response criteria, it is understandable because the use of the software will certainly be very different from the use of hardware that can respond directly or naturally.

The data of the affective aspect was obtained by observation during the learning process. The observation sheet has been developed based on revised Bloom's Taxonomy (Forehand, 2010). The result can be seen in Table 6. The average score in the experiment group is 81.83 and the average score in the control group is 76.34.

Table 6 - Affective score

No	Criteria	Average Score in Control Group	Average score in Experiment Group
1.	Receiving	81.52	90.41
2.	Responding	80.46	81.92
3.	Valuing	73.15	76.22
4.	Organizing	74.66	80.78
5.	Characterization by a value complex	71.93	79.81
Total Average score in Affective Aspects		76.34	81.83

In the affective assessment of the highest increase results obtained on the receiving criteria, this is because the Proteus display and also the interface graphics have an easy-to-understand view (Jumini, Trisnowati, & Dahnuss, 2020). So that students easy to receive information from Proteus. While the smallest increase results are obtained from responding criteria, because of the students are busy interacting with Proteus then they will ignore interactions with the surroundings, although low but the value is still above the fairness and still acceptable.

The result for students' performance (cognitive, psychomotor, and affective score) were combined and descriptive comparison indicated that the experimental group (M = 80.7; SD = 6.51) outperformed the score for the control group (M = 74.2; SD = 5.82). Further analysis was performed using an independent t-test, there was a significant effect for treatment in the experimental group, $t(72) = 3.068$, $p = .004$. (See Table and 7).

Table 7 - Mean score for both control and experimental group

	Performance				95% CI for Mean difference	t	df
	Experiment		Control				
	M	SD	M	SD			
Score	80.69	6.51	74.19	5.82	6.49, 6.49	3.068	72

In general, from the average score different of three Bloom's learning achievement, where either in the cognitive, psychomotor, and affective domain, it can be summarized that in this study, that using Proteus software in teaching-learning microprocessor and microcontroller in general, having its value-added, in line with several previous study (Yuan et al., 2007; Olamide & Joshua, 2012; Su & Wang, 2010; Mukherjee, Ray, & Das, 2014; Himawan, Suprianto, Thamrin, 2015).

4. Conclusion

This study was comparing the effect of teaching using simulation software using Proteus on students' learning performance, especially on the Programming and Arduino Microcontroller subjects in the experimental and control group. Students who are engaged in class through the implementation of Proteus software scored higher in performance tests involving cognitive, affective and psychomotor aspects. The result indicated that the average score was generally in favour of the experimental group in terms of cognitive, affective and psychomotor aspects, an interestingly, an insight into the cognitive aspect, creativity indicated a slightly increase. Based on this finding, Proteus can be recommended to be utilized as the simulation software, especially for programming and Arduino microcontroller class to improve students learning domains. Future research is suggested to focus on the effect of simulation software on nurturing students' creativity, which is expected to yield a significant contribution to literature.

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