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The Development of Students' Logical Thinking Skills Using Arduino as A Learning Utility in the Computer System Subject

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ABSTRACT

Logical thinking skills play an important role in learning computer system subjects, especially in basic logic gates material. The purpose of this study was to examine the growth of students' logical thinking skills in the computer system subject using Arduino as a learning utility. In this research, a pre-experimental design with a pretest-posttest one-group design was implemented. The 30 students of class X-RPL in SMK Sangkuriang Cimahi are used as subjects in this study. A test with a logical thinking indicator was used to assess the pupils' logical thinking abilities. The indicators consist of the ability to think logically, give an argument, and draw a conclusion. Based on n-gain analysis, the result shows that the student's ability in logical thinking was barely increased with a gain score of 0,214. More specifically, the application of Arduino has a bigger influence on the ability to think logically and give an argument than its influence on the ability to draw a conclusion.

Keywords*: Logical thinking; Arduino; Learning utilities; Computer system*

A. INTRODUCTION

In the 21st century of education, it is important for students to have critical thinking skills. Critical thinking skills are the ability to think logically, reflectively, systematically, and productively in order to make effective conclusions and decisions (Hidayah, Salimi, & Susiani, 2017). Because of that, logical thinking has become an important part of students' critical thinking abilities. According to Incikabi, Tuna, & Biber (2013), logical thinking is essential to improving students' academic performance as well as conquering daily challenges.

Indonesia, through the Ministry of Education, Culture, Research, and Technology, has determined graduate competency standards for vocational schools. This is stated in Regulation No. 5 of 2022,

which is to demonstrate complex abilities and ideas, conclude the results, and present arguments that support the thoughts based on accurate data. This is relevant to Albrecht's (2009) statement that the basic goal of studying logic is simply to become proficient in acknowledging premises, arguments, and conclusions.

Basic logic gates, one of the materials in computer systems subjects that are mandatory to learn at vocational school, require logical thinking ability. Nevertheless, students still lack the ability to think logically. It is proven by the preliminary test of logical thinking, which shows an average score of 48,67. The factors that influence low logical thinking skills include the limitations of the use of technology and the environment as learning tools, the lack of interaction between students and teachers, and the fact that the learning method used tends to be direct instruction only (Malik, 2011; Riyanto & Siroj, 2014).

The use of technology in the classroom has become more frequent over time. But there are not so many schools that use technology such as Arduino to facilitate learning. Whereas, in the previous study, the students were interested in building a circuit with Arduino (Ntourou, Kalogiannakis, & Psycharis, 2021). Moreover, Arduino could become an excellent way to attract students and others interested in electronics and programming (Galadima, 2014).

In this study, the implementation of logic gates in Arduino was made by creating a combination circuit that included three buttons as input and one LED lamp as output. The buttons and lamp are connected to illustrate symbols in each logic gate. This allows students to directly experience the combination of logic gates. So, it is expected that students will gain a better understanding of the topic as well as develop their logical thinking skills.

In this state, this study aimed to investigate students' logical thinking skills improvement in the Computer System subject that utilizes Arduino in the learning process. This relies on the idea that Arduino is believed to support students' learning. Furthermore, it may have an impact on students' logical thinking skills. As a result, it leads to the following research question: "How has the implementation of Arduino in the computer system topic affected the enhancement of students' logical thinking skills?".

B. METHOD

1. RESEARCH DESIGN

The pre-experimental design was used in this study with a pretest-posttest one-group design, in which only one group will get treatment. In this case, the application of the pre-experimental design is to compare the results of students' logical thinking skills before and after the treatment based on their pretest and post-test scores. In the initial test, 20 questions are given to the students to determine their initial logical thinking skills. After completing the test, students learn about basic logic gates using Arduino. Then, the students will take a final test with 20 questions of multiple choice to determine their logical thinking skills.

The process carried out in this study consists of 6 steps. In the first step, the interview with the teacher was carried out as an initial study. This is done to find out the obstacles that students faced and the learning method that is often used in learning computer systems subjects. After that, the test to assess students' logical thinking skills was developed. In this step, the validity of the test was checked by an expert. Then, tested its validity and reliability statistically. Its results are used to choose the items of the questions that apply in the pretest and posttest. Once the tests are ready, the preliminary test is carried out to determine the student's initial logical thinking skills. Then, the use of Arduino in learning basic logic gates was implemented in the classroom. For the next step, the students take a final test to find out their logical thinking skills after learning the material using Arduino. Finally, the data collected was processed and analyzed as planned.

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2. LOGICAL THINKING

Logical thinking is defined as a type of thinking in which the essence is in operating with concepts, judgments, and inferences based on logic laws that compare and associate them with actions or the totality of mentally logically valid acts or thinking operations associated with correlation patterns that allow matching current understanding in order to describe and transform objective reality (Samadovna, Narzullayevna, & Ergashevna, 2020). Tim Pusat Penilaian Pendidikan (2019) classifies logical thinking as part of the level 3 thinking process, which is reasoning. This level measures higher-order thinking skills that go beyond remembering and understanding. At this level, the thinking process includes analyzing, evaluating, creating, logical thinking, critical thinking, creative thinking, and solving problems in new contexts or uncommon situations.

3. ARDUINO

Arduino is an open-source platform for physical computing that is microcontroller-based. It is not only a development tool but also a combination of hardware, language programming, and a powerful Integrated Development Environment (IDE) (Banzi, 2011). IDE plays a role as software to write a program, compile it to binary code, and upload it to the microcontroller's memory. This microcontroller itself is a chip, or Integrated Circuit (IC) that can be programmed using a computer. It has a function to control input and output in the electronic circuit (Wisesa & Purwandari, 2021).

According to Banzi, there are some important reasons to use Arduino boards. These include an active user community to share user experiences, the growth of Arduino that makes it easier for the new user, inexpensive hardware because it can be easily accessed from the official website, and a multi-platform environment that can run on several platforms (Ismailov & Jo'rayev, 2022). But, the primary advantage of Arduino over other microcontroller programming platforms is its ease of use, which allows untechnical individuals to quickly learn the basics and construct their own creations (McRoberts, 2013). So, its use in the classroom will be very possible.

4. POPULATION AND SAMPLE

All students of class X in SMK Sangkuriang 1 Cimahi were chosen as the population of the study. In this study, one class selected using convenience sample technique. As a result, the experiment was carried out in the X-RPL class with 30 students.

5. DATA COLLECTION TECHNIQUES

The data in this study was collected using a test that was divided into two tests, which are the pretest and posttest. Each test consists of 20 questions of the type of multiple choice that has been tested for its validity and reliability. In order to measure students' logical thinking skills, each question of the test was made with logical thinking indicators that include the ability to think logically, the ability to give an argument, and the ability to draw a conclusion. Table 1 shows the distribution of the questions.

Table 1. Distribution of The Questions with Logical Thinking Indicator

Logical Thinking Indicator	Number of Questions	
	Pretest	Posttest
Ability to think logically	13	12
Ability to give an argument	2	4
Ability to draw a conclusion	5	4
Total Questions	20	20

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6. DATA ANALYSIS TECHNIQUES

In the development of the test, the correlation product moment was used to test the validity of the questions. Meanwhile, its reliability was tested with Cronbach's alpha. This reliability test will be carried out using SPSS software.

The data from the student's test result was analyzed using normalized gain (n-Gain). This analysis technique is used to determine the improvement of students' logical thinking skills. Therefore, it can be concluded that the experiment was effective. This analysis was done using Microsoft Excel 2019. The categorization of the result is described in Table 2.

Table 2. Categories of Gain Criteria (Hake, 1999)

Percentage (%)	Criteria
g >= 0,70	High
0,30 <= g < 0,70	Medium
g < 0,30	Low

C. RESULT AND DISCUSSION

1. RESULT

This study was conducted on the basic logic gate material of computer systems subjects in class X-RPL SMK Sangkuriang Cimahi. Before beginning the experiment using Arduino in the classroom, the instrument for the test was developed. It was prepared by referring to the three indicators mentioned before. Based on this, multiple-choice tests with 20 questions for the pretest and posttest were made to measure students' logical thinking skills. To make sure that the instruments for the test used in this study are valid and reliable, this test was carried out after trying out the questions with the students. The validation of the test was calculated with a correlation product moment using Microsoft Excel 2019. Table 3 below shows the validity results of the questions.

Table 3. Validity Test Results

Pretest			Posttest		
Item Questions	r_{xy}	Results	Item Questions	r_{xy}	Results
Ability to think logically-1	0,46	Valid	Ability to think logically-1	0,58	Valid
Ability to think logically-2	0,43	Valid	Ability to think logically-2	0,44	Valid
Ability to think logically-3	0,47	Valid	Ability to think logically-3	0,42	Valid
Ability to think logically-4	0,42	Valid	Ability to think logically-4	0,55	Valid
Ability to think logically-5	0,45	Valid	Ability to think logically-5	0,41	Valid
Ability to think logically-6	0,53	Valid	Ability to think logically-6	0,56	Valid
Ability to think logically-7	0,40	Valid	Ability to think logically-7	0,51	Valid
Ability to think logically-8	0,61	Valid	Ability to think logically-8	0,40	Valid

Ability to think logically-9	0,50	Valid	Ability to think logically-9	0,45	Valid
Ability to think logically-10	0,41	Valid	Ability to think logically-10	0,40	Valid
Ability to think logically-11	0,61	Valid	Ability to think logically-11	0,52	Valid
Ability to think logically-12	0,41	Valid	Ability to think logically-12	0,55	Valid
Ability to think logically-13	0,42	Valid	Ability to give an argument-1	0,55	Valid
Ability to give an argument-1	0,57	Valid	Ability to give an argument-2	0,43	Valid
Ability to give an argument-2	0,39	Valid	Ability to give an argument-3	0,46	Valid
Ability to draw a conclusion-1	0,37	Valid	Ability to give an argument-4	0,43	Valid
Ability to draw a conclusion-2	0,44	Valid	Ability to draw a conclusion-1	0,40	Valid
Ability to draw a conclusion-3	0,38	Valid	Ability to draw a conclusion-2	0,38	Valid
Ability to draw a conclusion-4	0,47	Valid	Ability to draw a conclusion-3	0,37	Valid
Ability to draw a conclusion-5	0,38	Valid	Ability to draw a conclusion-4	0,36	Valid

Based on the table, all questions are valid to be used as tests of logical thinking skills. The reliability test is also determined using Cronbach's alpha technique. It was calculated using SPSS software and the results of the reliability test can be seen in Table 4.

Table 4. Reliability Test Results

Cronbach's Alpha		Results
Pretest	Posttest	
0,78	0,84	Reliable

Both the pretest and posttest in Table 4 show that the value is greater than 0,7. This means that the instrument is consistent with the results and can provide data that is relevant to the situation. As a result, the questions are reliable to use for the logical thinking skills test.

In finding the result of the pretest and posttest scores, the data of the student's scores was input into Microsoft Excel 2019 and then the average of the scores was calculated. Based on the calculation, the average score on the test was 48,67. After implementing Arduino in the learning process, the average test score increased to 59,67. The result of both tests is shown in Figure 1.

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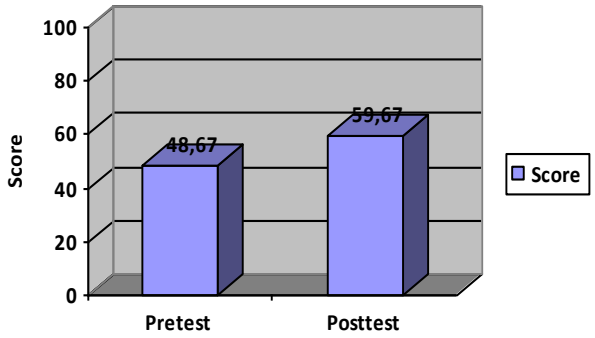

Figure 1. The Average of Pretest and Posttest Score

In order to determine the change in students' scores after the pretest and posttest statistically, the test of n-gain was conducted. It showed an improvement in the student's test result with a gain score of 0,214, which is in the low category. In conclusion, the Arduino learning tool has a low impact on students' logical thinking skills.

The effectiveness of Arduino for learning basic logic gates was measured using tests that included indicators of logical thinking skills. The results of the pretest and posttest showed improvement. But it is necessary to analyze the result of the student's logical thinking skills on each indicator. Figure 2 represents the percentage of the test results based on each indicator of logical thinking.

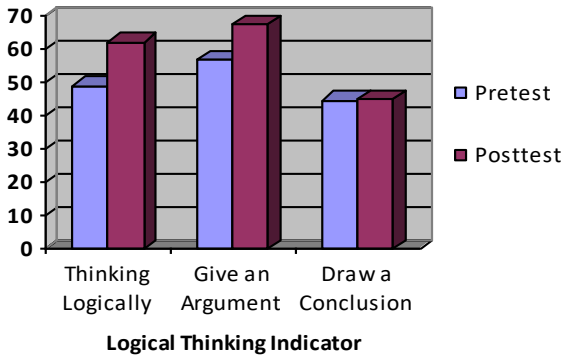

Figure 2. Percentage of Students' Logical Thinking Skills

The chart shows the percentage of the student's achievement in each logical thinking indicator. In general, there is a rise in each indicator of logical thinking skills. But the highest improvement is happening in the ability to think logically, which increases from 48,97% to 61,94% of students mastering this ability. Meanwhile, the ability to give an argument increased from 56,67% to 67,50%. For the ability to draw a conclusion, it slightly increased from 44,67% to 45%. Based on the results, using Arduino for learning basic logic gates has a greater impact on the ability to think logically and give an argument. However, it has minimal impact on the ability to draw a conclusion.

2. DISCUSSION

The use of Arduino as a learning utility could offer students additional possibilities to work on their logical thinking skills. This research discovered that students' logical thinking skills improved after using Arduino compared to before. It is relevant to some studies that Arduino can enhance computational logical thinking ability in block programming (Pratiwi, Sriyono, & Akhdinirwanto, 2018), improve HOTS of students in physics learning (Hadiati, Pramuda, & Matsun, 2023), and have an explicit effect on the computational thinking and conceptual understanding of electricity (Ntourou, Kalogiannakis, & Psycharis, 2021).

The learning process using Arduino provides an option for instructional aids to improve students' logical reasoning. So, more research and innovation are required to develop better learning tools for obtaining logical thinking as a competency required in 21st-century skills

D. CONCLUSION

According to the studies, it was found that after the experiment using Arduino as a learning utility, the students' scores in logical thinking skills improved. It has a stronger impact on the capacity to think logically and give an argument than it does on drawing a conclusion. For future research, it suggests implementing Arduino in other disciplines. Furthermore, it would be interesting to compare the development of logical thinking skills among students who use Arduino with students who use other learning tools.

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