The effect of physics learning using ardouno uno based media on higher-order thinking skills

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Abstract. The purpose of this study was to determine the effectiveness of contextual media with Arduino Uno-based media on students’ higher-order thinking skills on density material. The population of this research is class XII IPA MAN 1 Pontianak totaling six classes, with samples of class XII IPA A and class XII IPA B. This study is quasi-experimental with a pretest-posttest group design—sampling with a simple random technique to determine the experimental and control classes. The data collection technique used is a test in the form of pretest and posttest questions. The data analysis technique used is the one-party t-test based on the sig value and the normalized gain (N-gain). The results of research data analysis showed that contextual learning media with media based on Arduino Uno had a positive effect and improved students’ higher-order thinking skills than students who used conventional media. It is indicated by the results of the t-test with a value of sig. The post-test score is 0.001, and the results of the improvement test with the N-gain of the experimental class are in the medium category, higher than the control class category, namely low. So that learning physics using learning media based on Ardouno Uno has a positive effect and can improve students’ Higher Order Thinking skills.

1. Introduction
Physics learning is a branch of natural science that determines a process that emphasizes a fact, concept, principle, theory, or law. The ideas that exist in physics have the basis of grouping several non-verbal presentations, which ultimately have an abstract tendency that requires the ability to describe them [1]. Learning physics in the classroom must be supported by media that can change students’ perceptions of learning physics. Students’ perception in the learning process in class is that the concept of physics is complex. The learning process is related to the transfer of concepts, skills, and values between teachers and students [2]. A teacher has a vital role in the learning process. A teacher must have an exciting learning innovation that makes students interested in learning physics. Students’ low physics learning outcomes are caused by factors including the material in the book, which is felt to be too theoretical to be understood, is still less effective in learning media, the learning media used and selected by the teacher is not correct, the students are not optimal to be involved in a learning process and class activities that are not optimal dominated by teachers or educators [3]. The renewal of learning in the 2013 curriculum sees the need for higher-order thinking skills to run the objectives of achieving the curriculum learning [4].

Information obtained from students of MAN 1 Pontianak that learning physics is considered difficult due to the lack of understanding of the concepts being taught. The difficult understanding obtained by MAN students occurs in Density material when observing irregular objects; students
assume that the density of uniform objects and irregular objects is the same. In addition, the students of MAN 1 Pontianak have difficulty in doing a practicum. Practical tools available in schools are still limited in terms of the number and quality of devices. The practicum tools used still use simple tools and do not have automated tools. The problem that exists at the school is that there are no Arduino Uno-based teaching aids with sensor-assisted or technology-based tools, one of which is to use an Arduino Uno Microcontroller-based automation laboratory tool. The learning media based on the Arduino Uno microcontroller is quite effective and easy to understand in the teaching and learning process according to the characteristics of the supporting media. The research and learning process results using the Arduino Uno microcontroller can provide motivation and improve students’ High Order Thinking Skills. The students are said to handle problems if they can examine problems by combining their knowledge in new situations. This ability can be known as High Order Thinking Skills. Skills that allow students to connect, manipulate and change understanding with their experience critically and creatively in making decisions to solve problems. There are several realms of thinking from Bloom with the categories of analyzing, evaluating, and creating/creating [5].

Higher-order thinking skills are students’ active abilities when facing unusual problems, uncertainties, questions, and dilemmas. This ability continues to develop forward, providing valid results in accordance with knowledge and experience [6]. Meaningful experiences are beneficial for students’ learning so that students’ high-level abilities are realized. Higher-order thinking skills include cognitive skills in the realm of analyzing (C4), evaluating (C5), and creating (C6) [7]. Students must be able to explore the questions given, assess the problems that occur, and create the problems they face. Indicators to measure higher-order thinking skills include [8]: 1) Analyze incoming information and divide or structure information into smaller parts to identify patterns or relationships. Able to recognize and distinguish the causes and effects of a complex scenario. Identify or formulate questions. 2) Evaluating provides an assessment of solutions, ideas, and methodologies using suitable criteria or existing standards to ensure the value of effectiveness or benefits and creating hypotheses, criticizing, and testing. Accept or reject a statement based on predetermined criteria. 3) Creating is making generalizations of an idea or perspective on something. Design a way to solve the problem. Organize elements or parts into a new structure that has never existed before. Humans have several abilities that can be developed through experience. The experience occurs because of human interaction with both physical and social environments [9]. Physics learning requires learning media that can make students understand the material from virtual to real.

Media Contextual Teaching and Learning is a learning concept that helps teachers relate the material being taught to real-world students and encourages students to connect their knowledge and its application in real-life [10]. Arduino Uno-based learning media is a media that is developed automatically. In the experiment in the actual laboratory, the calculations are done manually. Using the density practicum tool based on the Arduino Uno microcontroller, the calculation results can be observed directly on the LCD screen. The learning media measures density using an Arduino Uno microcontroller with the help of ultrasonic sensors and load cells. Ultrasonic sensors function to determine the distance of the object’s surface to measure the object’s volume. Whi le cell functions as a sensor to find the mass of objects. So that the density of objects can be calculated automatically, both regular and irregular solids. The learning media based on the Arduino Uno microcontroller applies scientific procedures that students can do. Scientific procedures are an effort to train students’ higher-order thinking skills. Changes that arise because the learning process is effective, namely meaningful learning. That is, these changes bring specific effects, meanings, and benefits for students [11]. It also determines the effectiveness of learning by looking at the impact on students. Students who take part in direct learning will have the ability to formulate and find concepts [12]. This ability is used to solve problems and problems faced by students in real life.

The effectiveness of this research can be measured from student learning outcomes which become a minimal statement regarding student abilities [13]. Suppose the learning process is carried out with the correct and appropriate stages. In that case, the explanation description can achieve the research
objectives related to the effectiveness of contextual media with Ardouno Uno-based media on students’ higher-order thinking skills on density material.

2. Method
This study was conducted using a quasi-experimental design with a pretest-posttest control group design [14]. The population of this research is class XII IPA MAN 1 Pontianak with six classes. Sampling was carried out using a more straightforward random sampling method which required a homogeneous population [15]. A homogeneous population means that each class has the same condition or no difference between one class and another. Determination of homogeneous population or not using homogeneity test, normality test, and one-way ANOVA test. The data collection technique used a test with pretest and post-test questions in the form of multiple choices. The homogeneity test (variance) uses Levene’s test to find out the research sample is homogeneous. Normality test with Kolmogorov-Smirnov to show the data in a normally distributed state. The data analysis technique uses parametric statistics which data is typically distributed and homogeneous. The parametric statistic uses the right-hand t one-tailed test to determine the effect and the Ngain test to determine the improvement of students’ higher-order thinking skills. The one-tailed t-test uses SPSS 18 software assistance in the data analysis process. Test the hypothesis by looking at the value of sig. obtained from the analysis through the SPSS 18 program. The category of improving students’ higher-order thinking skills is seen by using the N-gain equation [16] as follows:

$$N - gain = \frac{posttest \ score - pretest \ score}{maximum \ possible \ score - pretest \ score}$$

Classification of normalized N-gain values can be seen in Table 1. Below [17].

| Score N-gain | Classification |
|--------------|----------------|
| 0.70 < N-gain ≤ 1.00 | High |
| 0.30 < N-gain ≤ 0.70 | Medium |
| N-gain ≤ 0.30 | Low |

3. Result and Discussion
3.1 Result
Learning physics using Arduino Uno during the COVID-19 pandemic towards the new normal period is very effective for students. Learning media based on the Arduino Uno microcontroller is a learning media that instill concepts and stages in implementing the practicum. Students can calculate the density of objects, both regular and irregular objects, so effective learning is carried out. T-Test Results Posttest and Control Class Scores can be seen in Table 2.

| Table 2. N-gain of Experiment Class and Control Class |
|-----------------------------------------------------|
| Class | N | Average Post-test | Average Pretest | N-gain | Classification |
|-------|---|------------------|----------------|--------|----------------|
| Experiment | 40 | 18,70            | 10,231         | 0,375  | Medium         |
| Control  | 40 | 15,54            | 8,891          | 0,251  | Low            |

Determination of the sample is viewed by looking at the homogeneity of the population. Homogeneity in the population was seen by Levene’s test, normality test, and one-way ANOVA test. The student’s initial abilities were obtained from the pretest scores before the two groups received treatment. Analysis of the pretest scores showed that the value of sig. (2-tailed) of 0.140, which means it is greater than the significance level of a. So it can be seen that the initial abilities of the experimental class and control class students before receiving treatment were the same.

The difference in learning outcomes of higher-order thinking skills in experimental class and control class students is seen from the post-test scores. The post-test scores were tested statistically using a two-party t-test using SPSS 18. There is no difference in the average post-test scores of the experimental class and the control class seen from the sig value. (2-tailed) which is compared with a
significance level of 5% or 0.05, it can be seen that the value of sig. (2-tailed) is 0.0021, which means it is smaller than the significance level of a. So it can be seen that there are differences in learning outcomes of higher-order thinking skills between experimental class and control class students. Furthermore, to determine the effect and effectiveness of the treatment given in the experimental class, a follow-up test was carried out using the right-hand one t-test. A one-sided t-test was carried out through the SPSS 18 program. Based on table 3, it can be seen that the value of sig. (1-tailed) of 0.0015, which means it is smaller than the significance level of 5% or 0.05. So it can be concluded that the treatment (learning using contextual media) with learning media based on the Arduino Uno microcontroller) given in the experimental class has a positive effect on students’ higher-order thinking on density material.

The improvement of students’ higher-order thinking ability learning outcomes can be seen from the N gain test scores of pretest and post-test between the experimental and control classes. The results of the analysis are presented in Table 2 below. Based on table 2, it is known that the N-gain classification of the experimental class and the control class is different. The experimental class N-gain value is 0.375 and is included in the medium category. The N-gain value for the control class is 0.251 and is classified as low. So it can be concluded that the treatment (learning using contextual media) with the Arduino Uno microcontroller-based media given in the experimental class can improve students’ higher-order thinking skills on density material.

The difference in treatment given to the two samples has affected students’ higher-order thinking skills. Based on the hypothesis test results, the difference in the average post-test scores of the experimental and control groups, there is a difference indicated by the value of sig. (2-tailed) 0.0021 < 0.05 significance level. Previously, it was known that the initial abilities of the students of the two groups were the same (the results of the two-tailed t-test, the pretest score was sig. 0.140 > sig. a 0.05). Then a further test to determine the effect of treatment is known to be the value of sig. (1-tailed) 0.001 < 0.05 significance level, meaning that the treatment given in the experimental class has a positive effect on students’ higher-order thinking skills. The results of the N-gain test show that the experimental class N-gain classification is greater than low control class N-gain classification. The N-gain values indicate it for the experimental and control classes, 0.375 and 0.251, respectively. Based on the hypothesis test results, it can be concluded that the treatment given in the experimental class in the form of learning using contextual media with media based on the Arduino Uno microcontroller is more effective in achieving students’ higher-order thinking skills on density material.

3.2 Discussion

Measuring the density of an irregular object uses a container filled with water. The whole system is conditioned to zero, so the density is the same. The object to be measured the density is inserted into a container filled with water. The ultrasonic sensor will read the increase in water height due to new objects entering the container. The increase in water will be read as the total volume of the object. The Arduino Uno microcontroller will recalculate the density according to the command given. The LCDs are the readings ordered from the microcontroller to display the mass, volume, and density of the object being measured. The measurement of the density of irregular objects is carried out using natural stone. The volume will increase for each additional mass of natural stone, but the density will always be the same. This is due to the similar characteristics of natural stone. Table 3 below shows the results of natural stone density measurements measured using Ardouno Uno microcontroller along with manual measurements:

From table 3, it can be seen that the results of the density test using the Ardouno Uno microcontroller have measurement results that are close to the results of manual calculations. With a measurement error using this tool of 1.44%. By testing the error of the Ardouno Uno microcontroller tool compared to the manual, it has a small error so that the tool used can improve students’ Higher Order Thinking skills.
Table 3. Testing the Density of Natural Stone

| Testing | Density (g/cm$^3$) | Manual | Tool |
|---------|-------------------|--------|------|
| 1       | 2.66              | 2.67   |
| 2       | 2.65              | 2.67   |
| 3       | 2.65              | 2.68   |
| 4       | 2.67              | 2.68   |
| 5       | 2.67              | 2.67   |

Learning that involves higher-order thinking skills requires clarity in conveying facts to eliminate ambiguity and confusion to improve students’ attitudes in thinking [18]. The learning media Arduino Uno provides facts related to the value of the density of objects that are read automatically so that students do not feel ambiguous. The opinion follows the results of students’ higher-order thinking skills as seen from students’ answers in working on questions [19]. The results of the improvement analysis are presented in Table 4.

Table 3 provides information that students have succeeded in practicing higher-order thinking skills during the learning process. It can be seen from the results of increasing student answers after treatment. The improvement result of students in the experimental class is higher than that of students in the experimental class. However, the indicators for evaluating experimental and control class students experienced the same increase. Some indicators of higher-order thinking ability starting from the initial ability are zero, meaning that students don’t know about it. The treatment given has given a significant increase to a value of 45. The increase in experimental class students who take learning with contextual media and Arduino-based learning media is higher than students in the control class. Students’ initial knowledge has been constructed through physics learning, which applies to digging students’ prior knowledge into complete knowledge through hands-on practical experience using Arduino Uno-based practicum tools [20]. Students find, process, analyze existing data and then compare them with existing physical concepts. These results follow previous research conducted [21], which stated that the mastery of concepts of students who studied with the guided inquiry was higher. The higher-order thinking abilities of students were well trained. The improvement of students’ higher-order thinking skills can be seen from the pattern of students’ answers to higher-order thinking skills.

Table 4. Improving Students’ Higher Order Thinking Ability

| Indicator | Experiment | Control |
|-----------|------------|---------|
|           | Pre  | Post | N-gain | Pre | Post | N-gain |
| Analyze incoming information and share information into smaller parts to recognize the relationship. | 22   | 41   | 0,405 | 47   | 31   | -0,865 |
| Able to recognize and distinguish factors cause and effect of a scenario | 6    | 80   | 0,575 | 3    | 26   | 0,181  |
| Formulating questions | 109  | 115  | 0,157 | 93   | 97   | 0,126  |
| Provide an assessment of the solution, ideas, and methodologies by using criteria appropriate | 90   | 130  | 0,478 | 58   | 111  | 0,567  |
| Make a hypothesis, and do the test | 2    | 15   | 0,118 | 8    | 23   | 0,176  |
| Accept or reject a statement based on predetermined criteria. | 3    | 84   | 0,678 | 0    | 75   | 0,570  |
| Generalize an idea | 53   | 67   | 0,714 | 45   | 62   | 0,594  |
| Designing a way to solve the problem. | 30   | 41   | 0,087 | 6    | 38   | 0,241  |
| Organizing elements or parts Becomes structure new | 0    | 45   | 0,317 | 0    | 3    | 0,018  |
Figure 1. The use of the Arduino Uno tool by students and pictures of the density tool.

The pattern of student answers leads to problem-solving by applying higher-order thinking aspects. Students make assumptions (hypotheses) on the problems that exist in the problem. The hypothesis is tested by analyzing the calculation results in a way that they understand. Students give reasons to support the hypothesis according to the calculations’ results [22]. The process of students in solving problems has proven that learning using media based on the Arduino Uno microcontroller is successful in training students’ higher-order thinking skills. These results are consistent with the statement that students’ success in practicing higher-order thinking skills depends on the ability of students to apply, reorganize or rearrange, and embellish their knowledge in situations where students think following existing circumstances. [23]. Students’ thinking levels at the level of analyzing, evaluating, and creating are considered higher-order thinking abilities. The success of students in practicing higher-order thinking skills affects the success of student learning. Treatment needs to be given to students to change thinking patterns, see the problem as a whole, solve problems, and then concretize abstract knowledge because it is an important thing that students need to have.

4. Conclusion

Based on the results of the data analysis of the experimental and control class post-test scores, obtained in the medium category and the N-gain value for the control class in the low category. The results of this research analysis can be concluded that learning physics using learning media based on Arduino Uno has a positive effect and can improve higher-order thinking skills. Based on this, the arduino uno learning media effectively achieves students’ higher-order thinking skills on density material. The treatment given in the experimental class in the form of learning physics using learning media based on the Arduino Uno microcontroller has a positive impact on students’ higher-order thinking skills. The influence and improvement are also supported by the learning process that has trained students’ higher-order thinking skills.

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