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# THE IMPLEMENTATION OF PHYSICS LEARNING THROUGH ONLINE MODE DURING PANDEMIC COVID-19 USING METACOGNITIVE KNOWLEDGE-BASED MATERIALS

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**ABSTRACT**

This study aims to analyze the effect of metacognitive knowledge-based physics teaching materials (MKBPTM) on the ability to analyze metacognitive knowledge. These teaching materials were used in online learning during the Covid-19 pandemic. The research employed a post-test only control group design. The participants were divided into two groups: the experimental group consisting of 120 students and the control group comprising 124 students, who came from public senior high schools. The results showed that the MKBPTM experimental group had better learning outcomes than the control class using conventional-based teaching materials (CBPTM). The hypothesis testing results indicate a difference in the average score between the experimental and control groups' metacognitive knowledge analysis skills (MKAS). The results suggest that MKBPTM has an influence on MKAS compared to CBPTM.



Keywords: analytical skills; MKAS; teaching materials; metacognitive knowledge

## INTRODUCTION

Physics is a basic science that deals with nature's behavior and structure. It is taught to find order through observation of the nature (Giancoli, 2014). Lederman (2006) states that physics is not just a collection of knowledge, but more than that, science is a way of thinking, a form of investigating, and a body of knowledge. Based on this view, physics is nothing but basic knowledge that studies the behavior of objects, technological products, and natural phenomena that contain the values of life. Kim et al. (2018) suggest that physical equations are needed to study natural behavior. Through equations, the characteristics of natural behavior and their interactions with other natural conditions can be understood. For example, rain is a natural behavior that does not stand alone. Precipitation occurs because of evaporation, sublimation, and melting in addition to other methods.

There are two essential aspects of learning, namely teaching and teaching outcomes. Good education will also produce good learning results. Teaching is a respectable profession where a teacher must make changes in values and knowledge that can be useful for students in facing their daily lives (Bropy, 2010; Wentzel, 2020). Kerr and Lloyd (2008); Gillborn et al. (2018) stated that teaching would be more meaningful if concepts, principles, and theories can be turned into practical experiences so that students can understand real situations. Based on these two views, teaching is an activity carried out by teachers to help students achieve goals that are beneficial to them. Therefore, teaching using a fun method is needed so that the knowledge and values taught can be well understood by students (Rebecca, 2003).

Efforts to achieve teaching goals depend heavily on the use of teaching strategies. A good teaching strategy is a modified strategy. Therefore, nowadays, much research on strategy implementation and testing has been carried out by re-

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searchers (Jonassen, 1991; Napoli, 2004; Langley & Eylon, 2006). This shows that the importance of teaching strategies has been recognized and understood by teachers. However, many of the new strategies developed by teachers do not use the theoretical basis of student learning and development. Many teachers fail to implement a plan even though the process has been very successful in other schools (Ramsden, 1998; McLaughlin, 2013). This condition is often experienced by teachers in Indonesia. Every learning model developed by the teacher based on the Ministry of National Education policies cannot be adequately implemented because they are not suitable for geographical conditions, environment, culture, and student characteristics. Maybe the learning models are ideal for individual schools but not for other schools. This problem has happened since Indonesia's independence. Therefore, to overcome this problem, the research team developed "multi-conceptual based physics teaching materials" as a component for implementing physics teaching strategies during the Covid-19 pandemic.

Why must the teaching materials be developed?. The reason is that the teaching strategy is closely related to teaching materials developed by teachers. The content of physics teaching materials generally consists of facts, concepts, laws, principles, formulations, theories, postulates, and rules. The more complex the material content, the more complex teaching strategies are required. Teaching materials are learning tools that contain aspects of knowledge used to achieve specific learning objectives as set out in the lesson plan (Lewis, 2009).

Teaching materials are closely related to the dimensions of knowledge. Anderson & Bloom (2010) & Hermawati (2020) divided knowledge into four dimensions: factual, conceptual, procedural, and metacognitive knowledge. Factual knowledge is knowledge about facts or reality. Several facts which have the same characteristics are called conceptual knowledge. Procedural knowledge refers to the relationship between concepts. Meanwhile, metacognitive knowledge is related to the integration of conceptual and procedural knowledge in solving problems. Among the four dimensions of knowledge, the dimension of metacognitive knowledge is the knowledge that must be developed in physics teaching materials. As Lin (2001) asserts, metacognition is the ability to understand and monitor ways of thinking and its implications for its activities. Metacognition is thinking about thinking (Dawson, 2008; Shanon, 2008; Coskun, 2010).

Metacognition is "*high-order cognition about cognition*" (Veenman et al., 2006; Wernke et al., 2011). Metacognition is a process of thinking about cognitive abilities, cognitive strategies, and cognitive tasks (Duque et al., 2000). This explanation implies that metacognition is more oriented towards higher-order thinking processes, and one of the components of higher-order thinking is critical thinking skills. This is in line with Jacobs and Paris (cited in Michalsky et al., 2009), who state that metacognition is "self-awareness of one's knowledge, about one's task, about thinking, and self-control of cognitive processes." Jacob and Paris's statement implies that people who have good metacognition abilities will automatically think at high levels because the ability to control cognitive activity will make it easier to perform higher-order thinking skills (Özsoy & Ataman, 2009; Pennequin et al., 2010). This is why, in the 21st-century, where information technology develops rapidly, higher-order thinking skills are needed to solve very complex problems.

Meanwhile, according to the view of Santrock (2007), strategic knowledge is about how and when to use specific procedures to solve problems. Arends (2010) proposed a similar view , that metacognitive knowledge is knowledge about learners' cognition and learning about when to use conceptual or procedural knowledge to solve problems. From these two definitions, it can be argued that the indicator of metacognitive knowledge is problem-based knowledge. This is stated by Torkamani (2010), that metacognitive knowledge is the knowledge that is used to solve problems (problem-solving). More than that, according to Lee & Baylor (2006) and Caliskan & Sunbul (2011), metacognitive knowledge is the knowledge that is used to organize thought processes to solve problems. Thus, it can be concluded that the characteristics of metacognitive knowledge are problem-solving based.

Based on the explanation above, it can be concluded that to optimize students' thinking skills in the 21st-century; it is very important to teach metacognitive knowledge. To make this happen, this dimension of knowledge must be included in teaching materials. The research team has designed and developed physics teaching materials based on metacognitive knowledge during the Covid-19 pandemic since the beginning of 2000. The development process followed development research procedures and the materials have been revised three times based on the feedback from experts of pedagogy, material experts, and language experts. At the end of September

2020, it was declared feasible to be implemented through research activities. Therefore, the questions in this study are as follow: (1) How big is the MKAS average score obtained by students in the experimental group?; (2) How big is the the MKAS average score obtained by students in the control group?; and (3) Is there any difference in the average MKAS score between students in the experimental group and students in the control group?.

Both groups were taught in online learning but different teaching materials were used. The experimental group used physics teaching materials based on metacognitive knowledge, while the control group was taught using cognitive-based teaching materials. The differences between the two teaching materials are presented in Figure 1.

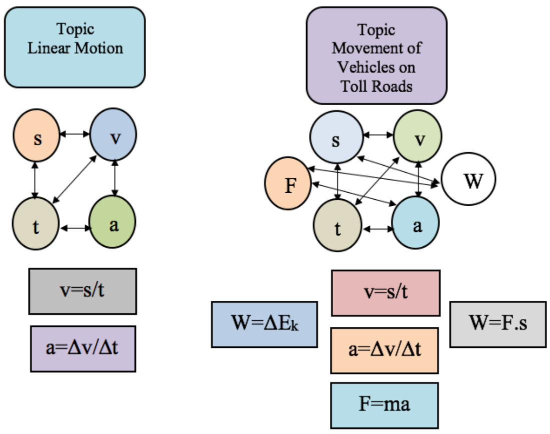



**Figure 1.** Differences in Cognitive and Metacognitive based Teaching Materials

Based on cognitive knowledge, physics teaching materials are teaching materials developed by teachers based on the materials' order in the physics textbook. In Makassar, high school physics teachers, in developing physics teaching materials, always refer to the book "Physics-Principles with Applications" by Giancoli (2014). The teachers' physics teaching materials follow the order of the materials in Giancoli's book. For example, for the subject: One Dimensional Kinematics, the sub-subjects order is reference frame and displacement-Average Velocity-Instantaneous Velocity-Acceleration-Motion at Constant Acceleration-Solving Problems. In a review from the learning aspect, such an arrangement of physics teaching materials has some weaknesses, namely: (1) it is theoretical and conceptual; (2) examples of questions developed are limited to the use of formulations (such as s=vt dan a=Δv/Δt); and (3) the variables taught are lacking. The development of physics teaching materials like this is called the development of cognitive-based teaching materials. Because these teaching materials only emphasize the development of students' ability to remember, understand, and apply knowledge. At the same time, the aspects of analyzing, assessing, creating are inadequate.

The 21st-century learning has changed the focus of learning, from the cognitive aspect to the metacognitive aspect. Therefore, a paradigm shift is needed to prepare physics teaching materials from cognition-based to metacognition based. Why? Because only metacognitive knowledge can develop students' thinking abilities, such as the ability to analyze, assess, think critically, and think creatively. This is consistent with Santrock (2007); Ellis et al. (2014) view that metacognitive knowledge is strategic knowledge about how and when to use specific procedures to solve problems. The same thing was stated by Arends (2010), that metacognitive knowledge is knowledge about learners' cognition and knowledge about when to use conceptual or procedural knowledge to solve problems. There is a similarity between Arend's, Ellis', and Santrock's view, that is solving problems. Meanwhile, problem-solving requires the ability to apply metacognition (or higher-order thinking). Therefore, the research team developed physics teaching materials based on metacognitive knowledge. How is the structure of the teaching materials based on metacognitive knowledge?

The scheme for developing physics teaching materials based on metacognitive knowledge is shown in Figure 1 above. The development mechanism is not based on the order of materials in the textbook, but it is based on events around the students' environment. For example, the topic of vehicle movement on the highway is chosen. Of course, many things can be expressed by the motion of vehicles on toll roads, such as the motion of a car that is accelerated slowly, the motion of a car that is driven constantly, and the motion of a car that is ahead of other cars. These incidents were the topic of discussion. In terms of variables to be developed in teaching materials, there are two variables, namely the main variable which includes speed (v), acceleration (a), distance traveled (s), and travel time (t) (such as s=vt and a=Δv/Δt) and supporting variables such as force (F), work (W), and kinetic energy (E). The combination of the primary and supporting variables will enrich the cohesiveness between variables so that in studying straight motion or vehicle motion, the kinematic aspect (primary variable) is not taught as well as the dynamics aspect (complementary variables).

The advantages of physics teaching materials based on metacognitive knowledge are as follows: (1) students can understand the relationship between kinematic variables and dynamic variables; (2) students have a comprehensive understanding of motion and force; (3) students have no difficulty in learning the dynamics of motion because they have been introduced earlier to the topic of kinematics; and (4) the materials allow students to develop metacognitive thinking skills. Here are some sample questions from cognitive knowledge-based teaching materials with metacognitive knowledge-based teaching materials, as presented in Table 1.

**Table 1.** Examples of Learning Materials based on Cognitive and Metacognitive Knowledge

| Example Problems on Teaching Materials | |
|---|---|
| **Cognitive Knowledge-Based Teaching Materials** | **Metacognitive Knowledge-Based Teaching Materials** |
| The car is driven at a constant 20 m/s highway. At 200m in front of the car, a truck turns. Specify:<br>a. Minimum slowdown of the car so as not to hit the truck.<br>b. Car average speed | The car is driving at a constant 20 m/s highway. At 200m in front of the car, a truck overturned. Specify:<br>a. Minimum slowdown of the car so as not to hit the truck.<br>b. Car average speed<br>c. If the mass of the car is 1000kg, determine the amount of braking force.<br>d. Effort by the braking force<br>e. The maximum kinetic energy of the car |
| Note:<br>This example problem only introduces the formula: $S=vt$ and $v^2=v_o^2 \pm 2as$ | Note:<br>This example problem presents the procedure: $S=vt$, $v^2=v_o^2 \pm 2as$, $F=ma$, $W=FS$, and $E=\frac{1}{2}mv^2$ |

Based on the explanation of these two types of teaching materials, physics teaching materials based on metacognitive knowledge contribute to analyzing metacognitive knowledge compared to physics teaching materials based on cognitive knowledge. Physics teaching materials based on cognitive knowledge can also contribute to students' metacognitive knowledge-analytic skills; however, the quality is still low. Therefore, to determine that physics teaching materials contain metacognitive knowledge, a measuring tool is needed to measure the teaching materials after being used by the students. The measuring instrument is called "Metacognitive Knowledge Analysis Skill (MKAS)". This measuring instrument follows the metacognitive knowledge principles with the following characteristics: (1) problem-based question statements; (2) containing more procedural knowledge. The more procedural knowledge in the questions, the higher the level of metacognitive knowledge is.

## METHODS

To answer the problem formulation above, the method used in this study is a quasi-experimental research design with a post-test only control group. This study involved two groups of students, namely, the experimental group using metacognitive knowledge-based physics teaching materials (MKBPTM) and the control group using conventional-based teaching materials (CBPTM). Both groups used online learning. The experimental group comprised students from SMAN 2 Makassar and the control group consisted of students from SMAN 9 Makassar, Indonesia. The students were between 15 and 17 years old. The total number of samples in this study is shown in Table 2. The number of physics teachers used as teachers in online learning is four teachers for the experimental group and two teachers for the control group. The four teachers have more than ten years of teaching experience. So, they are considered expert teachers.

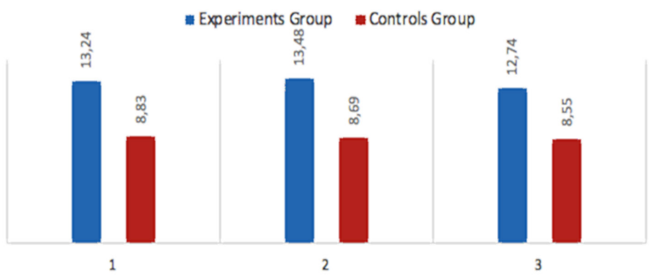
**Table 2.** Number of Students in Each Experimental and Control Group

| Experiment Group (SMAN 2 Makassar) | | Control Group (SMAN 9 Makassar) | |
|---|---|---|---|
| **Class Name** | **The Number of Students** | **Class Name** | **The Number of Students** |
| Class XI MIA.1 | 31 | Class XI MIA.1 | 32 |
| Class XI MIA.2 | 30 | Class XI MIA.2 | 31 |
| Class XI MIA.3 | 29 | Class XI MIA.3 | 30 |
| Class XI MIA.4 | 30 | Class XI MIA.4 | 31 |
| Total | 120 | Total | 124 |

Prior to implementing online learning, the research team conducted intensive training on teaching materials, made power points, used zoom (online internet), and used google forms as a learning evaluation tool. Training activities were carried out for eight days in weekdays. After implementing the training, teachers shared the information to students through WhatsApp group to determine online teaching schedules. Each teacher taught in two classes, in which the teaching was done in a scheduled manner according to the provisions of the school schedule. The time required for each stage of online learning was 90 minutes per week and lasted three weeks. In the fourth week, the MKAS test was conducted simultaneously using google form.

## RESULTS AND DISCUSSION

During the the teaching stage, nothing happened that would change the research plan. Everything was based on the plan, from the beginning to the data collection stage. The collected data are in the form of 244 answer sheets. The answer sheets were checked and given a score, then analyzed descriptively and inferentially. The processing results which describe the two groups' analytical abilities are shown in the following Figure 2. It can be seen in Figure 2 that there is a difference in the mean score of the metacognitive knowledge analysis test between the experimental group and the control group.

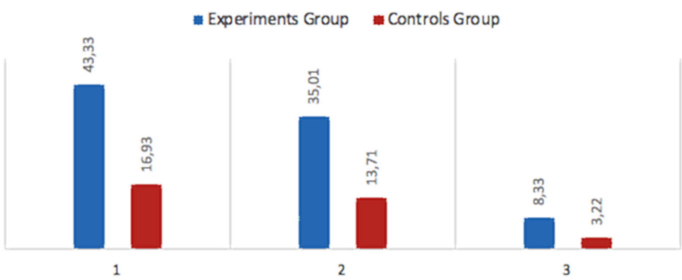



Note:
1= All gender, 2= Females, 3= Males

**Figure 2.** Mean Score of the Metacognitive Knowledge Analysis Test

Overall regardless of gender, the mean scores of the experimental group were x1 = 13.24 (20) and Sd1 = 4.25, while the control group was x2 = 8.83 (20) and Sd2 = 4.22. Meanwhile, when viewed from gender differences, it turns out that the experimental group was still superior over the control group. The female students' mean score in the experiment group was 13.48 (20), and the control group was 8.69 (20). Likewise, for male students, the experimental group obtained 12.74 (20), and the control group obtained 8.55 (20). So, the overall description of the experimental group has better learning outcomes than the control group.

The results shown in Figure 3 show the results of the metacognitive knowledge analysis test. The experimental group has a difference in the average score with the control group, where the experimental group is superior to the control group. Likewise, in terms of the percentage of students who obtained scores above or equal to 14, the experimental group was still superior to the control group. From these data, it can be concluded that a multi-conceptual based physics teaching strategy is superior to a mono-conceptual based physics learning strategy. However, hypothesis testing is still needed to strengthen this conclusion further.




Note
1= All gender, 2= Females, 3= Males

**Figure 3.** Percentage of Students Who Scored ≥ 14 (Maximum Score of 20)

As for testing the hypothesis of the difference in metacognitive knowledge analysis test scores between the experimental and control group, the t-test was used. The results of testing data processing are as shown in Table 3.

**Table 3.** Hypothesis Testing

| No | Variable | Group | |
|---|---|---|---|
| | | Experiment | Control |
| 1 | Number of the sample (n) | 120 | 124 |
| 2 | Average Score (X) | 13.24 | 8.83 |
| 3 | Standard Deviation (S) | 4.25 | 4.22 |
| 4 | Variants ($S^2$) | 18.06 | 17.81 |
| 5 | $t_{table}$ for degrees of freedom ($n_1+n_2-2$) = 242 and $\alpha$=0.05 | 1.97 | |
| 6 | $t_{value}$ | 8.50 | |

Based on the information on the hypothesis testing data in Table 3, the results show that t = 8.50> t table = 1.97. This test supports the above description statement, that overall, a multi-conceptual based physics teaching strategy has an advantage over the ability to analyze metacognitive knowledge compared to a mono-conceptual based physics teaching approach.

Although there are limitations in this study, the difference in the average MKAS score of the student group using MKBPTM and the student group using CBPTM indicates that the use of MKBPTM is relatively good in growing MKAS. This means that overall the two groups received the same treatment except for different physics teaching materials. Thus, it can be stated that MKBPTM can relatively grow MKAS. Therefore, it is natural that learning experts believe that the preparation of teaching materials largely determines the success of a lesson through alignment between individual differences and learning objectives (Riding & Douglas 1999; Pitchers, 2002; Sadler-Smith et al, 2012).

Teaching strategies are mostly used to apply learning theory in useful ways and achieve targeted learning outcomes (Nottingham, 2015). On the other hand, Marzano (2003) and Durlak et al. (2011) states that the primary component that affects student learning outcomes is teaching strategy. However, the success of the system is largely determined by the development of teaching materials. That is why the teaching strategy and teaching materials are not separated. Both become the main components in learning. Therefore, for the teaching strategy to be achieved optimally, the teaching materials developed must facilitate student learning (Romiszowski, 2008; Archibald, et al., 2011). The purpose is to direct and guide students to be able to think at higher levels. In line with the suggestion put forward by Dhull and Verma (2020), physics is a complex subject that requires the use of skills such as critical thinking, logical thinking, and problem-solving skills. To possess these skills, teachers must do strategic planning based on the characteristics of physics lessons. One type of knowledge that can foster higher-order thinking skills is metacognitive knowledge, as stated in the introduction. Based on the expert's view expressed above, the description of physics teaching materials based on metacognitive knowledge is stated in the knowledge tree diagram shown in Figure 4.

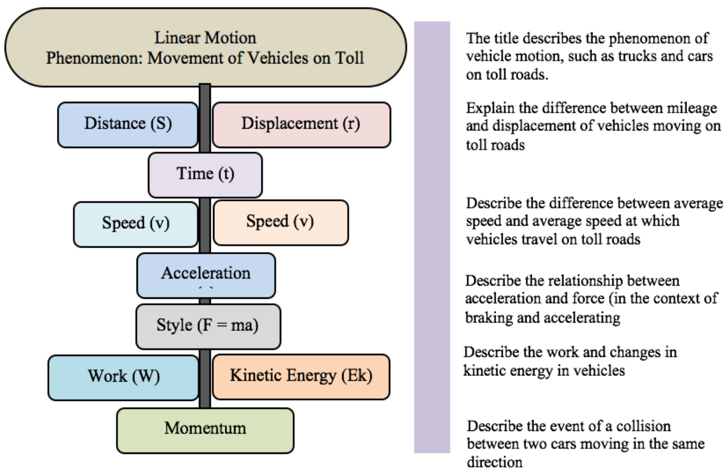



**Figure 4.** Tree Diagram of Material Content as Teaching Plan Ideas

The development of physics teaching materials must refer to concrete objects and everyday events because it will help students connect abstract concepts and the real world (Brown et al., 2009). As seen in the knowledge tree diagram above, vehicles' movement on toll roads is an everyday occurrence full of concepts and procedures, and the relationship between ideas and techniques. This is the basic principle of metacognitive knowledge. The relationship between concepts and methods is discussed in an everyday event (Stoica et al., 2011). Thus, the development of physics teaching materials based on metacognitive knowledge is a strategy that effectively supports the 21st-century learning paradigm.

There are two variables involved in this research: physics teaching materials based on metacognitive knowledge and MKAS. When online learning took place, there were many reports concerning internet network disruptions experienced by students and teachers. Such a condition significantly affect the results of the study. Also, the atmosphere of students studying at home is very much influenced by the needs of the student's home environment and the students' psychological factors. So, the researchers predicted that the average MKAS score obtained by the experimental group and the control class was not entirely due to the treatment given. This is the limitation experienced by the research team while researching the Covid-19 pandemic.

Physics teaching materials based on metacognitive knowledge are a model of learning materials that are needed in the 21st-century, which promote critical, creative, communication and collaboration thinking. So that the results of the research will greatly help physics teachers in developing physics teaching materials to support 21st-century learning. Also, the implementation of online learning during the study has provided students with skills in using the internet technology, especially how to make teaching materials in applications such as Powerpoints, how to use online learning applications, such as Zoom, and how to make assessments using Google form.

## CONCLUSION

The mean score of metacognitive knowledge analysis skills (MKAS) in the experimental group was 13.24 (20), and that of the control group was 8.83 (20). The hypothesis testing results indicate a difference in the average MKAS score obtained by the two groups at the confidence level $\alpha$=0.05. Thus, MKBPTM has an influence on MKAS compared to CBPTM. The results can be inferred that teaching strategies can be used to achieve various learning objectives. Meanwhile, the teaching strategies are closely related to the development of teaching materials. The teaching materials are part of the teaching strategy. One of the causes of students being unable to solve problem-based or metacognitive knowledge-based problems is students' difficulties in connecting concepts and procedures. This shows that the teaching materials used are more theoretical or traditional. Teaching materials are important tools in studying school subjects as part of the curriculum. Based on the findings of this study and the views of learning experts, it can be concluded that teaching materials (including MKBPTM) are the main components in learning that determine the achievement of learning outcomes.

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