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Metacognitive Skills in STEM Integrated Discovery Learning Models for Kinetic Gas Theory in High School

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Abstract

Metacognitive skills are an important component supporting mastery of concepts in studying physics. This research aims to describe students' metacognitive skills through STEM-integrated discovery learning on kinetic gas theory material at SMAN 1 Dolopo. This research uses the One-Group Pretest-Posttest Design method, where in this design, one experimental group is selected to measure students' metacognitive abilities. The research on the kinetic theory of gas metrics was carried out in class XI Merdeka 4. The research took place in the odd semester of 2022-2023. The results of students' metacognitive skills show an increase in every metacognitive aspect, namely planning skills. The increase occurred in every meta-cognitive aspect, namely planning skills, which were originally 66.4 to 73.7. Monitoring skills, which previously received a score of 60.4, also changed to 73. Evaluating skills possessed by students also changed, from 64.4 to 67.4. Significant increases occurred from the pretest to the posttest, especially in the monitoring skills category. From the table, it is known that the increase occurred from the moderately developed to the developed category. Based on the research and discussion results, the metacognitive skills of class XI Merdeka 4 students are included in the developing category after receiving STEM-integrated discovery learning. This is in line with research that states that the inquiry learning model, including the discovery learning model, positively affects students' metacognition in learning. High-performing students may have better metacognitive skills than low-performing students. High-performing students may have better metacognitive skills than low-performing students.

Keywords: discovery learning; metacognitive skill; STEM

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INTRODUCTION

The kinetic theory of gases is defined as the idea that gases are formed due to molecules moving very quickly and randomly. The kinetic theory of gases explains that the properties of gases (for example, pressure) use Newton's laws for particle motion (Giancoli, 2016; Handayani, 2020). The kinetic gas theory

material teaches about the behaviour of gas particles, which are described in macroscopic quantities, namely pressure, volume, temperature and microscopic quantities of collision frequency, speed and energy. Kinetic gas theory also studies the characteristics of ideal gases from a macroscopic and microscopic point of view (Nurmayanti, 2015).



The obstacles experienced by students in understanding this concept are caused by difficulties in connecting macroscopic quantities (pressure, volume, and temperature) with microscopic ideal gas quantities, such as speed, collision frequency, and kinetic energy (Kanginan, 2013; Robertson & Shaffer, 2013). Difficulties arise when students often confuse the speed of particle motion, which is a microscopic quantity, with macroscopic processes in understanding thermodynamic quantities (Kautz et al., 2005). Microscopic gas behaviour cannot be observed directly, thus adding to students' difficulties in analyzing gas behaviour (Yaumi, 2019). Metacognition is needed to improve mastery of concepts in gas kinetic theory material.

One effort to overcome student difficulties is through conscious facilitation and integrating macroscopic, sub-microscopic, and symbolic representations by involving metacognition in the learning process (Thomas & Anderson, 2014). Metacognitive skills have become important in 21st-century education (Miharja et al., 2019; Zohar & Barzilai, 2013). The application of metacognitive learning activities can involve students' activeness in studying science, especially in building students' independence so that they have the skills to be able to ask questions well, look for answers to questions asked, and find answers independently (Darmawan et al., 2018; Nielsen, 2019). It has been recognized that analytic metacognition is important for how older children acquire more sophisticated scientific and mathematical concepts in school. Growing evidence that even young children have the capacity for procedural metacognition raises the question of whether and how this ability is involved in conceptual development and a recognized link between analytic metacognition and conceptual change. In the cases we examined, children were better at using

analogies than explicit ones in acquiring new concepts (Smortchkova & Shea, 2020).

Therefore, integrating appropriate learning models can encourage the development of metacognitive skills, one of which is using the discovery learning model. Evidenced by research results show that the application of Discovery Learning-based worksheets can improve metacognitive skills and student learning outcomes (Junina et al., 2020). Apart from using the discovery learning model, using metacognitive skills is very suitable for increasing mathematical modelling competence, especially for someone new to the STEM field (Stohlmann & Albarracín, 2016). The results of other research show that the application of STEM-based learning has a big influence on learning, in this case, improving students' metacognitive skills (Markandan et al., 2022; Wangguway et al., 2020). The SELM significantly empowers the metacognitive skills of students (Darmawan et al., 2020).

Growing evidence that even young children have the capacity for procedural metacognition raises the question of whether and how this ability is involved in conceptual development as well as a recognized link between analytic metacognition and conceptual change: in the cases we examined, children were better at using analogies. Explicit in acquiring new concepts (Smortchkova & Shea, 2020). However, there is rarely an examination of the role of metacognitive skills at the stage of students' concept acquisition. Previous research focused more on improving and influencing models. Therefore, the state of the art and novelty of this research explores the metacognitive skills possessed by students during learning using the STEM-integrated discovery learning model.

METHOD

This research is aimed at finding out students' metacognitive skills. The

metacognitive skills referred to in this research are students' skills in planning, monitoring, and evaluating when solving problems and independently achieving learning goals. Metacognitive skills in this research will be measured using a questionnaire referred to (Cooper et al., 2008). The method used in this research is a One-Group Pretest-Posttest design, as seen in Figure 1.

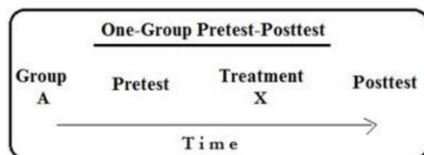


Figure 1 Research method

In this design, one experimental group is selected to measure students' metacognitive abilities with a research scheme, as depicted in Figure 2.

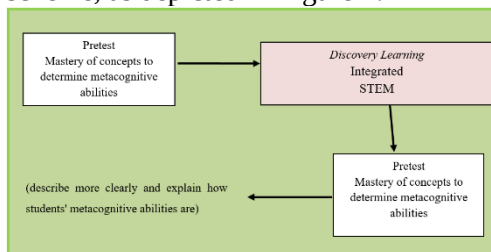


Figure 2 Research process

Students' metacognitive skills were measured using a questionnaire through a pretest to determine the initial situation, they were treated with the STEM-integrated Discovery Learning learning model, and finally, they were given a posttest to measure students' metacognitive skills. The research was carried out on July 26-August 20, 2023. The research subjects were class XI Merdeka 4 students at SMAN 1 Dolopo taking Gas Kinetic Theory material in the odd semester 2022/2023.

The data obtained was then analyzed using metacognitive skills data based on metacognitive skills-based tests assessed with a Linkert scale score of 1-4. Next, these scores are converted into students' metacognitive skills scores, which include planning skills, monitoring skills,

and evaluating skills using the following formula:

$$\text{Value} = \frac{\text{score A}}{\text{score B}} \times 100 \quad \dots (1)$$

Where:

Score A = scores obtained for each metacognitive skill

Score B = score maximum

After that, the average value of each metacognitive skill activity is calculated using the following formula:

$$\text{Value} = \frac{\text{score x}}{\text{score y}} \times 100 \quad \dots (2)$$

Where:

Score X = total metacognitive score of all

students

Score Y = score maximum

Data on metacognitive skill scores based on metacognitive inventory tests and questionnaires are converted according to the categories in Table 1.

Table 1 Metacognitive skill criteria

Score	Criteria
$80 < x \leq 100$	Very developed
$60 < x \leq 80$	Develop
$40 < x \leq 60$	Quiet develop
$20 < x \leq 40$	Undeveloped
$0 < x \leq 20$	Very underdeveloped

(Fidiana et al., 2017)

RESULT AND DISCUSSION

Students' metacognitive skills are obtained based on the results of the metacognitive skills test given after working on concept mastery questions in the kinetic theory of gas material. Students' metacognitive skills were obtained based on a metacognitive inventory questionnaire at the end of each meeting, after doing the pretest and posttest. Data on students' metacognitive skill scores obtained through metacognitive skills-based tests, including planning skills, monitoring

skills and evaluating skills, are presented in a diagram. Based on the diagram above. The value of students' metacognitive skills can be seen based on metacognitive skills-based tests.

The students' answers showed that the reasons given and the explanations were wrong in concept or that they did not understand at all. They thought the value

of V was volume and used the Boyle Guy Lusac equation to work on the problem. The questions should be written clearly and speed-based on interview reinforcement. Students tend to ask their friends when they can't do it, so they actually don't understand what they are doing at all.

Table 2 Results of metacognitive skills

Metacognitive skill indicators	Pretest Average	categories	Posttest Average	categories
Planning skills	66	Develop	74	Develop
Monitoring skills	60	Quiet develop	73	Develop
Evaluating skills	64	Develop	67	Develop

Based on Table 1.2, in the pretest, students got an overall average score of 63, which means they are classified as developing. Then, the metacognitive skills posttest result was 71, which means it is classified as developing. This is in line with research which concludes that based on the metacognitive inventory questionnaire used as supporting data for metacognitive skills, it shows that metacognitive skills have been trained in the very good and good categories where students control their learning process (Widyawati A T & Nasrudin, 2019).

Table 2 shows that the metacognitive skill scores of students after receiving STEM `integrated Discovery Learning overall increased. This is in line with research stating that the inquiry learning model, including the Discovery learning model, positively affects students' metacognition in learning (Haerullah, 2020; Muhali et al., 2021). Meanwhile, according to other research, it is said that the results of the analysis show that STEM education in high school can be concluded that students' metacognitive skills are in good condition (Wahyuni et al., 2020). The lowest metacognitive skill score is in the monitoring indicator, which gets a

score of 60.

This could be because students tend to have difficulty monitoring and controlling the completion steps that have been used and managing and controlling the time used. Most students can only answer one question from the two points asked in number 4. Students answered questions correctly but were still careless. Students could answer question no. 4a but could not answer question no—4 b, which relates to the kinetic energy of gases. In line with research, students often have misconceptions about the relationship between molecular attractive forces and the kinetic theory of gases. According to research, students must organize and plan their own learning strategies to study the material and complete the test sheets (Aisyah et al., 2015).

Students' metacognitive skills obtained through questionnaires include planning, monitoring, and evaluating skills, as presented in Figure 1. The data will be presented as a bar diagram to compare and explain students' metacognitive scores before and after learning STEM-integrated discovery learning on gas kinetic theory material.

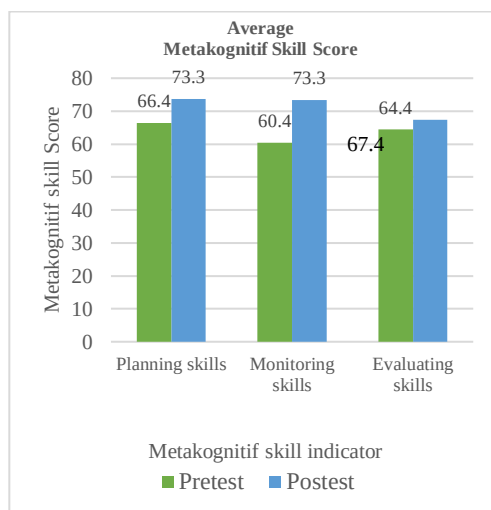


Figure 1 Graph of average metacognitive skills of students

From Figure 1, it can be seen that the students' metacognitive skill scores after receiving STEM-integrated discovery learning increased. This is in line with research that states that the inquiry learning model integrated with virtual laboratories can improve students' metacognitive skills in learning (Muhali et al., 2021). The increase occurred in every meta-cognitive aspect, namely planning skills, which were originally 66.4 to 73.7. Monitoring skills, which previously received a score of 60.4, also changed to 73. Evaluating skills possessed by students also changed from 64.4 to 67.4. Based on the results of the monitoring ability interview, students were unable to identify the difficulties they were facing because they felt everything was difficult, and they didn't know how to do it correctly, so they were confused about where to fix it. Meanwhile, for evaluation skills, students only think about collecting answers directly without thinking again about the process of working on the questions.

Improvements occur in every meta-cognitive aspect. A significant increase occurred during the pretest to the posttest, especially in the skill monitoring category. From Table 2, it is known that the increase occurred from the moderately

developed to developed category. This means that students' developed abilities include carrying out problem-solving plans on questions. Be aware that organising and controlling your work is based on your initial knowledge. Be aware of monitoring and controlling the solution steps that have been used. Be aware of managing and controlling the time used. This is by research which states that based on students' answers, students' skill evaluation scores are influenced by their lack of care in determining the steps or methods in solving questions as found in the metacognitive skills assessment rubric (Adita, 2016).

For the evaluating skills category, the results show developing criteria, which means students can apply evaluation when working on questions. This is reflected in the student's answer, which has included a conclusion in accordance with the statement that the student has used his evaluation skills, which can be seen from reviewing whether there was anything that was overlooked in working on the assignment by writing the conclusion at the end of the answer (Nurfiah, 2016).

Individual differences in answers may be due to students having varying levels of innate ability or prior knowledge in a particular subject, which may influence their metacognitive abilities. High-performing students may have better metacognitive skills than low-performing students (Rahmawati & Setyaningsih, 2022). Thus, the diversity of students' metacognitive ability results is also influenced by various factors, not only learning models but also difficulties in integrating intellectual, cognitive and motivational variables. Perceptions of activities and tasks influence how they approach learning and their judgments about their ability (Borkowski et al., 2000).

CONCLUSION

Description of students' metacognitive skills results include planning skills,

monitoring skills, and evaluating skills. Based on the research and discussion results, it can be concluded that the metacognitive skills of class XI Merdeka 4 students after receiving STEM-integrated Discovery Learning are in the developing category. The results of the students' metacognitive skills, which were originally in the pretest in categories, were quite developed, and their development also experienced an increase to become developed during the posttest. Based on the monitoring ability interview results, students could not find out the difficulties they were facing because they felt everything was difficult. They didn't know how to do it correctly, so they were confused about where to fix it. Students only think about immediately collecting answers without thinking again about the process of working on the questions. The increase occurred in monitoring skills, which initially received a moderately developed category in the pretest but were changed to developed in the posttest.

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