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Implementation of Differentiated Discovery Models to Improve Students' Understanding of Physics Concepts and Science Process Skills

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Abstract

This study aimed to improve students' understanding of physics concepts and science process skills by combining the discovery model with the differentiated instructions approach. This study used the Collaborative Classroom Action Research method, which was carried out in two learning cycles with 36 research subjects in class X.1 at a high school in Banjarmasin. Each learning cycle comprised several meetings involving the stages of plan, do/action, see/observation, and reflection. The results from cycle I indicated that 8.33% of students had completed all the indicators of learning objectives (ILO) related to understanding the physics concept of alternative energy. Furthermore, there was an enhancement in students' process skills, with an average increase of 37% falling into the "Less" category. The results in cycle I showed that learning activities required improvement for cycle II. The results in cycle II showed that 78% of students had completed all the ILO of understanding physics concepts, and there was an increase in students' processing skills with an average score of 66.67% in the "Good" category. An increased understanding of physics concepts with an N-Gain value in the "High" category had a strong positive relationship with an increase in science process skills in the "Medium" category. Based on the findings of this study, it was identified that the differentiated discovery model could improve students' understanding of physics concepts and science process skills because it could facilitate students' learning needs, thus providing implications for students' activeness and receptiveness to information learning physics in class.

Keywords: Discovery; Differentiated; Scientific literacy; Understanding of physics

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INTRODUCTION

Learning physics in the Merdeka Curriculum has two main elements in learning outcomes (*Capaian Pembelajaran* or *CP*): elements of understanding physics concepts and elements of science process skills (Kemdikbudristek, 2022). Science process skills can be identified through students' understanding of physics concepts (Lestari et al., 2020). Students with good science process skills will tend to have a good understanding of physics concepts; in other words, learning outcomes elements of science process skills have a positive relationship with learning outcomes elements of understanding physics concepts (Rosdianto et al., 2018; Sari et al., 2018). This indicates the crucial significance of nurturing and continually enhancing the elements of science process skills to facilitate the improvement of students' grasp of physics concepts. Unfortunately, it is regrettable that students' science process skills in the context of physics learning fall into the low category.

Based on the results of preliminary studies at a high school in Banjarmasin, it was known that students could not predict correctly, carry out investigations, analyze information, reflect on information, and were passive in asking questions. This affected students' low science process skills and understanding of physics concepts. A similar problem also occurred in grade X students of a private high school in Jakarta who had science process skills in the low category in all aspects (Rahma & Kusdiwelirawan, 2020). The low science process skills and understanding of physics concepts are caused by the implementation of learning models that are not optimal in training science process skills and are teacher-centered, so students tend to be passive, less skilled, more silent, and only pay attention to the lessons delivered by the teacher (Jalal et al., 2022; Putri et al., 2019; Rahmasiwi et al., 2015). Hence, there is a need to implement a learning model that can engage students actively in the learning process.

The model that is believed to be able to make learning more active is the discovery model. The discovery model is used to develop active learning methods by guiding students to identify, investigate, analyze, and construct understanding independently (Cintia et al., 2018) to improve students' science process skills (Hikmawati et al., 2021; Waruwu et al., 2023)

Enhancing student activity in learning for a positive impact on science process skills and comprehension of physics concepts requires a design approach centered around students. Therefore, teachers must consider students' learning needs when planning learning activities. A learning approach that can facilitate students' learning needs is a differentiated instruction approach (Marlina, 2019; Sari, 2023).

Differentiated Instruction (DI) is an approach to teaching that tailors instruction based on students' varying levels of understanding, interests, and other learning needs. This method prevents students from becoming easily frustrated in their learning process (Breaux & Magee, 2013; Tomlinson & Moon, 2013). Differentiated Instruction consists of three implementation aspects, namely content aspects, process aspects, and product aspects as an assessment (Colquitt et al., 2017; Khristiani et al., 2021). According to Tomlinson, the learning needs of students that are of concern in this differentiated instruction are students' learning readiness, interests, and learning styles (Tomlinson, 2001).

Students' learning readiness is their initial cognitive level before learning. The learning readiness of these students can be integrated into the process aspect. Student interest in learning is a type of assignment or assessment that students like; this interest in learning can be integrated into aspects of assessment products. The learning styles can be integrated into the content aspects presented according to students' learning styles in learning media.

Previous research findings state that the discovery model could increase student activity in learning by up to 89.7% in the high category (Handita et al., 2022; Kawuri & Fayanto, 2020), could improve students' science process skills (Sugiarti & Ratnaningdyah, 2020; Yuliati & Susianna, 2023) and understanding of physics concept (Aprilia et al., 2020). The implementation of this model also received a positive response from students in learning physics (Winarti et al., 2021). Other findings also state that learning models that applied a differentiated instruction approach in the learning process could improve students' understanding of physics concepts (Laia et al., 2022) and science process skills (Şentürk & Sari, 2018).

Based on the relevant references found, no discovery model has been studied using a differentiated instruction approach to improve students' science process skills and conceptual understanding in physics learning. Therefore, this study aims to improve students' science process skills and understanding of physics concepts by applying the differentiated discovery model, namely a combination of the discovery model and the differentiated instruction approach in a high school in Banjarmasin.

METHOD

This study used the Collaborative Classroom Action Research method by Kemmis & McTaggart (1988), which was carried out in two learning cycles. Each cycle had the Plan, Do/Action, See/Observation, and Reflection stages. The flow of each cycle can be seen in Figure 1.

This research was conducted in the Even Semester of the 2022/2023 school year at a high school in Banjarmasin. The data subjects of this study were class X.1, consisting of 36 students. The research instrument used was a test instrument to determine understanding of physics concepts and non-test instruments in the form of observation sheets for students' science process skills.

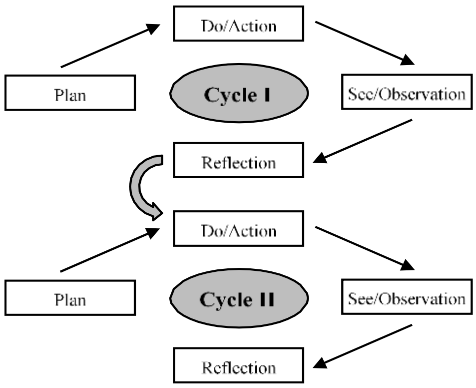

Figure 1 Research cycle flow by Kemmis & McTaggart (1988)

The learning model applied in this study could improve understanding of physics and science process skills if > 75% of students had succeeded in obtaining all the ILO, an average science process skill categorized as "Good", and an increased understanding of physics concepts as well as process skills science in the "Medium" category as shown by the N-Gain value between cycle I and cycle II. The ILO used in the cycle can be seen in Table 1.

Table 1 Objectives and Indicators of Learning Objectives

Learning Objectives (LO)	Indicators of Learning Objectives (ILO)
Describe the various types of energy and their transformations and categorize energy based on its use and availability in investigating the potential to be used as alternative energy in the surrounding environment.	1. Students can identify, describe, and categorize energy appropriately after making observations. 2. After conducting an investigation, students can properly analyze the impact of using non-renewable energy on the environment. 3. Students can analyze alternative energy sources appropriately after investigating energy potential in the surrounding environment. 4. Students can calculate energy used correctly after getting information on energy use.

The N-Gain value could be found using Equation 1 by Hake (1999). Interpretation of the N-Gain value category was presented in Table 2 by Hake.

Table 2 N-Gain value category

Value	Category
< 0.3	Low
0.3 – 0.7	Medium
> 0.7	High

The observed science process skill element indicators were observing skills (Sps1), asking questions (Sps2), predicting (Sps3), investigating (Sps4), analyzing information (Sps5), reflecting (Sps6), and communicating (Sps7) (Kemdikbudristek, 2022). Observation data of science process skills were categorized based on Table 3 (Fitriana et al., 2019).

Table 3 Science process skill category

Percentage	Category
0-20	Very Less
21-40	Less
41-60	Medium
61-80	Good
81-100	Very Good

Data on understanding physics concepts and science process skills were then analyzed using the Pearson Correlation Test with the help of a statistical program to determine the correlation between the two variables. Interpretation of Pearson Correlation values and Sig. (2-tailed) could be seen in Table 4 (Riduwan, 2003).

Table 4 Interpretation of the pearson correlation test

Data	Value	Conclusion
Sig. (2-tailed)	< 0.05	Correlated
	> 0.05	Not correlated
Pearson Correlation	0.00-0.20	Not correlated
	0.21-0.40	Weak correlation
	0.41-0.60	Medium correlation
	0.61-0.80	Strong correlation
	0.81-1.00	Perfect correlation

RESULT AND DISCUSSION

Data on the percentage of class X.1 students who had achieved all ILO for the elements of understanding physics can be seen in Table 5.

Table 5 Data of Students Obtaining ILO

Stage	Total Students
Pretest	0% (0 students)
Posttest Cycle I	8.33% (3 students)
Posttest Cycle II	78% (28 students)

Data on the percentage of science process skill elements based on observations in preliminary studies (X), cycle I (X1), and cycle II (X2) can be seen in Table 6.

Table 6 Science process skills percentage data

Indicator	X	X1	X2
Sps1	43.75	57.64	93.06
Sps2	29.17	38.19	62.50
Sps3	7.64	27.08	52.78
Sps4	22.22	46.53	61.81
Sps5	2.78	27.08	65.97
Sps6	1.39	13.19	50.69
Sps7	23.61	49.31	79.86
Average	18.65	37.00	66.67

Data on improving understanding of physics concepts and science process skills, as indicated by the N-Gain value, could be seen in Table 7.

Table 7 Improved understanding of physics concepts and science process skills

Variable	N-Gain Value	
	X1	X2
Understanding of Physics concepts	0.31 (Medium)	0.73 (High)
Science Process Skills	0.23 (Low)	0.47 (Medium)

The results of the correlation analysis of understanding physics concepts with students' science process skills can be seen in Table 8.

Table 8 Pearson correlation test results understanding physics concepts with science process skills

Data	Value
Sig. (2-tailed)	0.000 (Correlated)
Pearson Correlation	0.888 (Perfect correlation)

Preliminary study data stated that students' understanding of physics concepts and science process skills were in the "Low" category, so class action was needed to improve them; these actions would be carried out in cycle I.

Cycle I

Cycle I began with the creation of a plan. Making pretest-posttest questions, learning scenarios utilizing the discovery model and the discussion technique, PowerPoint slides, observation sheets for science process skills, and reflection sheets were all activities in creating this plan.

The next stage was to do/action by asking pretest questions in a separate meeting. Then, using PowerPoint media, built learning scenarios for two meetings with discussion activities and independent investigation based on the syntax of the discovery model. If two cycle I meetings had been held, then students were given posttest questions at separate meetings to find out their understanding of physics concepts at the end of cycle I.

During the action stage of implementing learning scenarios, two observers also carried out the see/observation stage to record student behavior and the development of science process skills during learning. The results of the observations would be used as material for reflection in the first cycle for improvement in the next cycle.

The last stage in cycle I was reflection. Based on the results of the students' pretest and posttest understanding of physics concepts presented in Table 5, it showed that no students had succeeded in achieving all the ILO with 0% on the pretest results; this was very reasonable because students had not studied alternative energy. The posttest results showed that three students achieved all of the ILO with 8.33%. The increase in students' understanding of physics from the pretest-posttest results was presented in Table 7, which stated an increase in the "Medium" category. These results were still far from the standard of success, namely > 75% of students, even though the increase had shown the "Medium" category, so the learning cycle still needed improvement to improve students' understanding of physics further.

Based on observations by observers, students whose understanding of physics was in the "Medium" category and below tended to be more passive than students whose understanding of physics was "High". This was evident during the discussion session, which was dominated by students in the "High" category. Students whose understanding of physics in the "Low" or "Medium" category tended not to show self-confidence if they joined a group dominated by students in the "High" category. In line with the findings of Ginanjar et al. (2019), which stated that when passive students saw their friends being more active, it made them less confident.

The observed students' science process skills are presented in Table 6, which shows that the average percentage value of all indicators was 37% in the "Less" category. In cycle I, students could observe, investigate, and communicate information in the "Medium" category. Other indicators, such as asking, predicting, analyzing, and reflecting, were in the "Less" category. Students who were less active in asking, predicting, analyzing, and reflecting on this information did not identify students with low cognitive ability but rather students with low science process skills in these indicators, which hampered their knowledge of physics ideas. Students who asked questions passively in class felt ashamed because they did not understand the lesson being addressed and were confused in analyzing and reflecting on the knowledge they had received. This is in line with Hariyadi's findings (2014), which stated that passive students asked questions because they were embarrassed to ask questions they had not understood, while active students asked if there were lessons that were difficult to understand (Izzah et al., 2022).

Students' lack of participation in learning or being passive greatly impacted science process skills and understanding of physics concepts, so further improvement was needed to activate passive students. Based on previous findings indicating that students were passive due to learning that was not driven by students' learning readiness and interests (Busthomy & Hamid, 2020; Meyanti et al., 2109), these findings would be used as material for reflection for the next cycle.

The researcher and the observer carried out reflection. The results of this reflection produced a follow-up plan to design learning that could facilitate learning readiness and interest in learning and activate students for all categories of physics concept understanding they had. Therefore, a differentiated instruction approach was chosen, which was believed to facilitate students' learning needs (Marlina, 2019) and would be combined with the discovery model to become a differentiated discovery learning model.

Cycle II

This research used a differentiated discovery model in cycle II, which implied that the learning scenarios were based on the discovery syntax. However, the grouping of students, use of media, assignment of assignments, and level of difficulty of the lesson were adjusted to the learning needs or differentiation of students.

The planning stage began with a diagnostic assessment to determine students' learning readiness, interests, and learning styles. The students' learning readiness (understanding of physics concepts) collected was based on prerequisite knowledge for alternative energy lessons. In contrast, the learning interest collected was information about the learning types and assignments students liked. The most common type of learning was discussion learning with student worksheets and work presentations, so that type was chosen to be adapted to the discovery model syntax.

Information on interest in assignments and learning readiness or students' initial understanding of physics concepts was used as material for consideration in dividing study groups, so students would be grouped based on the level of initial understanding and interest in the assignment that had been chosen.

The learning media used was web learning, a website that provided audio, visual, reading, and instructional learning materials simultaneously to facilitate each student's learning style. The students' work assignments were given the freedom to choose what type of work would be used to convey an understanding of physics concepts.

According to the level of understanding of students' physics concepts, student worksheets in cycle II were divided into 3 types. Groups with low levels would get Structured-type worksheets, medium levels would get Guided-type worksheets, while high-level groups would get Self Direct-type worksheets.

In cycle II, the posttest questions were rewritten to account for the ILO, which had not done much. The ILOs that had been achieved the most were ILO 1 and 4, while the least achieved were ILO 2 and 3. In the posttest questions in cycle II, there were fewer ILO 1 and ILO 4 by changing the quantities to ILO 2 and 3.

The do/action stage in cycle II was carried out in two meetings, with an additional meeting for the work presentation. In the first meeting, the learning scenario used the discovery model syntax, namely stimulation, problem statements, and data collection, which were implemented into worksheets to direct students to carry out investigations and predict the negative impacts of using non-renewable energy according to ILO 2 as a whole group. The second meeting used the discovery model syntax, namely data processing, verification, and generalization, which were implemented into worksheets to direct students to conduct investigations, analyze, and observe the natural potential in an area to be used as alternative energy according to ILO 3 and 4. At the end of the second meeting, each group was instructed to make a work according to the students' interests as a form of communicating the information obtained. The third meeting was a presentation session or presentation of students' work. Bulletin boards, posters, website articles, movies, podcasts, and other sorts of work were created by students. The examples of students' work can be seen in Figure 2.

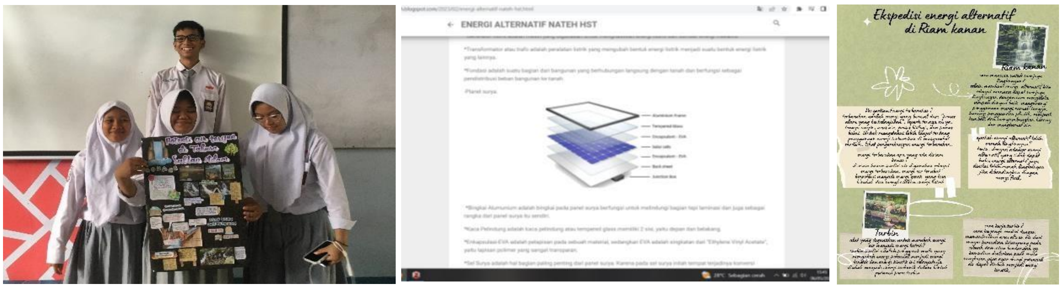

Figure 2 Wall magazines (left), website (middle), and posters (right)

The see/observation stage was carried out simultaneously with the do/action stage. At the end of the action stage, students were given posttest questions in cycle II to determine their understanding of final physics concepts.

The reflection stage was carried out based on the test and non-test data collected. The results of the second cycle posttest showed a very significant increase in the N-gain value seen in Table 7, which was equal to 0.73 in the "High" category. This increase brought 78% or 28 students to achieve all the ILO physics lessons set; this value can be seen in Table 5. These results met the improvement standards set by the researchers of > 75% of students. This showed that studying with an approach that could meet students' needs could help students enhance their understanding of physics concepts or student learning outcomes. This is in line with the findings of Herwina (2021), which stated that learning by meeting students' learning needs could optimize student learning outcomes (Herwina, 2021).

In addition to the increased understanding of physics concepts, students' activeness also increased; this activity could be seen from students' enthusiasm in participating in learning according to what students want. Student learning activities can be seen in Figure 3.

Figure 3 Discussion session (left) and creation (right)

The findings of observations of students' science process skills improved as well, with an N-gain value in Table 7 of 0.47 classed as "Medium," and the average value of each indicator of science process skills presented in Table 6 was 66.67% categorized as "Good." This already met the standard of improvement set by the researcher.

The highest indicator of science process skills in the "Very Good" category was the indicator of observing skills with 93.06%. After participating in cycle II learning, students could investigate and analyze information well, actively ask questions, and communicate the information well. Making predictions and reflecting skills were still in the "Medium" category. Based on observations, predicting and reflecting indicators had not been able to reach the "Good" category because students had not been able to provide logical reasons for the predictions they submitted, they only made predictions at random.

Students also only had adequate reflection skills because students were only limited to collecting and analyzing information without considering the purpose or usefulness of the learning being carried out. In this case, students needed the teacher's help directing them in reflection.

This increase in science process skills was also due to the active learning of physics. Learning became more active because it used the discovery model, which involved students in independent investigations and was presented in a way that suited the needs of students. This is in line with the findings of Anggraini et al. (2018), which stated that learning with the discovery model could make students active and carry out independent investigations.

Correlation of Understanding of Physics Concepts with Science Process Skills

In addition to expanding information from understanding physics concepts and students' process skills. Correlation analysis was also carried out to determine the relationship between the two variables. The results of the Pearson correlation test, which was carried out using a statistical program, can be seen in Table 8. The results of the person correlation test showed the sig. (2-tailed) of 0.000 with the conclusion that there was a correlation between the variables understanding physics concepts and science process skills, with a Pearson correlation value of 0.888, indicating a perfect correlation. In line with previous research findings, a significant correlation existed between students' science process skills and their knowledge of physics concepts or learning outcomes (Susilawati et al., 2019).

CONCLUSION

Based on the results of research, data analysis, and discussion, it could be concluded that the differentiated discovery model could improve understanding of the physics concept of alternative energy lessons with 78% of students who could obtain all learning objectives (ILO) and improve science process skills with an average of 66.67% in the "Good" category. An increased understanding of physics concepts with an N-Gain value in the "High" category had a perfect correlation with an increase in science process skills in the "Medium" category. The differentiated discovery model could improve students' understanding of physics concepts and science process skills because it could facilitate students' learning needs, thus providing implications for students' activeness and receptiveness to information learning physics in class.

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