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The influence of the discovery learning model with differentiated learning on the HOTS learning outcomes

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ABSTRACT

Higher-Order Thinking Skills (HOTS) is an important competency of the 21st century; yet, HOTS among high school students in Indonesia remains relatively low. This study aims to determine the effect of the discovery learning model with differentiated learning on the HOTS learning outcomes of high school students on the subject of motion systems. The research method employed was quantitative, utilizing a quasi-experimental design. The sample consists of two class XI Moving Biology classes from SMAN 61 Jakarta, selected through cluster random sampling, each consisting of 30 students. The research instrument consisted of a HOTS test with 13 essay questions covering cognitive levels C4 (analyzing), C5 (evaluating), and C6 (creating), an observation sheet, and a learning style questionnaire. The research results showed that the average posttest score of the experimental class (67.53) was higher compared to the control class (55.30). The t-test on the gain score showed a significant difference between the two classes. This study concludes that the discovery learning model with a differentiated learning approach has a significant effect on the HOTS learning outcomes of high school students on the topic of motion systems.

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INTRODUCTION

Education in the 21st century requires students to master critical thinking, creativity, collaboration, and communication skills to face global challenges and rapid technological developments in the era of the Industrial Revolution 4.0 (Nurhayati et al., 2024). The goal of education is not only to transfer knowledge but also to develop students' potential to become high-quality human resources through effective learning processes (Nur'aini & Darusyamsu, 2022). In line with this objective, the Indonesian Merdeka Curriculum emphasizes learning flexibility and promotes the development of Higher Order Thinking Skills (HOTS), such as analyzing, evaluating, and creating (Majidah et al., 2024).

However, students' HOTS abilities in Indonesia remain relatively low. Rahmi (2017) reported that the higher the cognitive level of test items presented, the lower the achievement of high school students in South Tangerang. Similarly, Gunawan et al. (2024) found that the HOTS mastery level of students at SMA Negeri 01 Mempawah Hulu was only 15.24%. These findings indicate that students still struggle to comprehend abstract concepts and solve problems analytically and creatively, particularly in biology learning.

Biology is a subject that demands strong conceptual understanding and analytical skills, especially in the human movement system topic, which covers the mechanisms of muscles, joints, and the skeletal system (Mukaromah, 2021). Teacher-centered learning practices often result in low student engagement, which negatively affects learning outcomes (Sholeh, 2024). Therefore, selecting an appropriate learning model is essential to support the development of students' HOTS (Abidin, 2019).

Discovery Learning is considered effective in promoting students' critical and creative thinking by encouraging them to explore, analyze information, and draw conclusions independently (Yunna, 2022). However, the effectiveness of this model may vary depending on students' learning preferences, indicating the need for a strategy that accommodates diverse learning styles.

Differentiated instruction is an approach that can meet individual learning needs by adjusting learning strategies, resources, and activities based on student profiles, including visual, auditory, and kinesthetic learning styles (Novinovrita & Setiawan, 2025). Process differentiation has been proven to enhance student engagement and improve learning outcomes (Almujab, 2023). Previous studies revealed that differentiated instruction positively affects student learning outcomes (Laia et al., 2022), and the integration of Discovery Learning with differentiation can further improve academic achievement (Rasuli et al., 2023; Sitanggang & Harahap, 2019).

However, research specifically examining the combination of Discovery Learning and process-based differentiation to improve students' HOTS in the human movement system remains limited. Therefore, this study aims to analyze the effect of implementing Discovery Learning combined with process differentiation on students' HOTS learning outcomes in the human movement system topic for grade XI senior high school students. The findings of this study are expected to contribute to improving the quality of biology learning and supporting the optimal implementation of the Merdeka Curriculum.

RESEARCH METHODS

Research Design

This study employed a quantitative approach using a quasi-experimental method with a pretest-posttest control group design. The research involved two groups: an experimental group that received treatment using the Discovery Learning model integrated with differentiated instruction, and a control group that was taught using the Discovery Learning model with a scientific approach. The design enabled the comparison of students' Higher Order Thinking Skills (HOTS) outcomes before and after treatment between both groups. The research design is illustrated in Table 1.

Table 1. Pretest-Posttest Control Group Design.

Group	Pretest	Treatment	Posttest
Experimental	R O_1	X	O_2
Control	R O_3	C	O_4

Description:

O_1 : Pretest score of the experimental class using the discovery learning model with differentiated instruction.

O_2 : Posttest score of the experimental class using the discovery learning model with differentiated instruction.

O_3 : Pretest score of the control class using the discovery learning model with a scientific approach.

O_4 : Posttest score of the control class using the discovery learning model with a scientific approach.

X : Treatment for the experimental class using the discovery learning model with differentiated instruction.

C : Treatment for the control class using the discovery learning model with a scientific approach.

Population and Samples

The population consisted of all Grade XI students enrolled in Biology classes (moving class system) at SMA Negeri 61 Jakarta during the academic year 2024–2025, totaling 89 students from three classes: Biology A, B, and C. The sample was selected using a multi-stage random sampling technique. First, purposive sampling was applied to define the population scope. Then, cluster random sampling was used to select two classes: Biology C as the experimental group and Biology A as the control group. From each selected class, 30 students were chosen using simple random sampling, resulting in a total of 60 participants.

Instruments

This study employed three types of research instruments: (1) HOTS test, (2) learning implementation observation sheet, and (3) learning style questionnaire. All instruments were designed to be valid, reliable, and aligned with the research objectives, particularly in measuring the effect of Discovery Learning combined with differentiated instruction on students' Higher Order Thinking Skills (HOTS).

A HOTS test consisting of 13 valid essay-type items that assessed students' skills in analyzing (C4), evaluating (C5), and creating (C6) based on Bloom's revised taxonomy. The reliability test using Cronbach's Alpha yielded a coefficient of 0.714, indicating the instrument was reliable. An observation sheet to measure the implementation of discovery learning and differentiated instruction across learning stages (introductory, core, and closing activities), scored using a 4-point Likert scale. A learning style questionnaire containing 30 Likert-type items divided into visual, auditory, and kinesthetic categories, used to support differentiated instruction in the experimental group.

Procedures

The research was carried out in three phases. During the preparation phase, the researcher identified the problem, developed research instruments, prepared lesson modules, and coordinated with the biology teacher. In the implementation phase, both groups received a pretest to measure baseline HOTS. The experimental group was taught using Discovery Learning integrated with differentiated instruction based on students' learning styles, while the control group followed the Discovery Learning model using a scientific approach. Each group underwent three sessions, covering subtopics of the human locomotor system. After the intervention, a posttest was administered to both groups. During the data processing phase, pretest and posttest data were validated and analyzed to determine the effect of the treatment on students' HOTS. The research procedure can be seen in full in Figure 1.

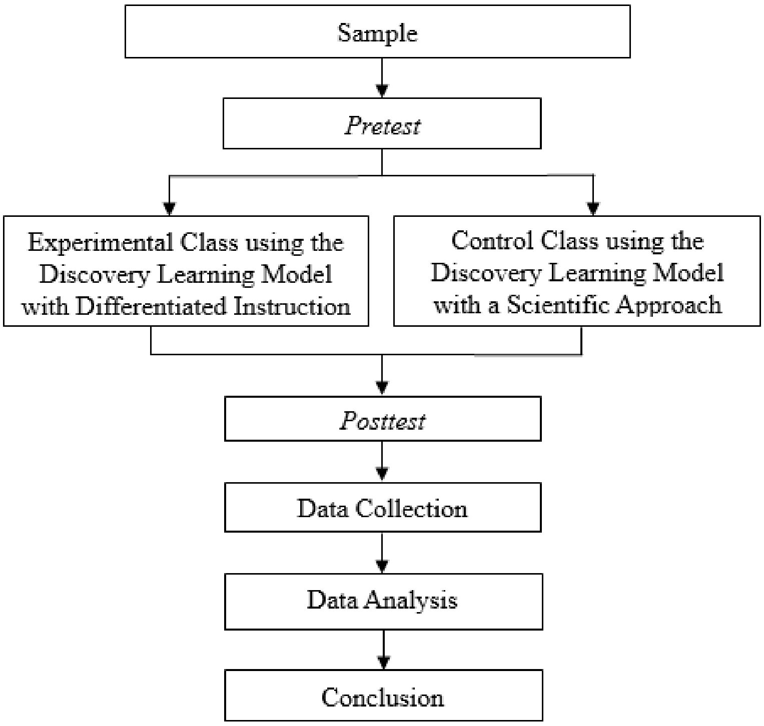

Figure 1. Research Procedures.

Data Analysis

Data analysis included descriptive statistics (mean, minimum, maximum, standard deviation) for pretest and posttest scores, observation results, and questionnaire data. Normality and homogeneity assumptions were tested using the Kolmogorov-Smirnov test and Levene's test, respectively. Inferential analysis involved an independent sample t-test to compare gain scores between the two groups at a significance level of $\alpha = 0.05$. Additionally, normalized gain (N-Gain) analysis was used to measure the effectiveness of the intervention in improving students' HOTS.

RESULTS

1. Students' HOTS Test Results

The data on students' Higher Order Thinking Skills (HOTS) in the experimental and control classes were obtained from the pretest and posttest scores on the human movement system topic.

Table 2. Learning Outcomes of Students' Higher-Order Thinking Skills (HOTS)

Data	Control Class		Experimental Class	
	Pretest	Posttest	Pretest	Posttest
Minimum Score	8,00	28,00	8,00	28,00
Maximum Score	38,00	86,00	42,00	94,00
Mean	20,27	55,30	20,80	67,53
Standard Deviation	8,27	16,64	7,62	17,78
Mean Gain Score	34,97		46,73	
Number of Students	30 Students		30 Students	

Based on the results presented in Table 2, students' HOTS in both groups improved after the intervention; however, the improvement in the experimental class was consistently higher than that in the control class. These findings indicate that the discovery learning model, combined with differentiated instruction, effectively provided meaningful learning experiences tailored to students' learning profiles, resulting in more optimal HOTS development.

This result aligns with Linda et al. (2019), who reported that discovery learning effectively improves HOTS by training students' problem-solving and critical thinking abilities. Furthermore, the application of process differentiation based on student profiles supports Tomlinson's (2013) findings, which emphasize that differentiated instruction enhances academic achievement and reasoning skills. Thus, the discovery learning model integrated with differentiated instruction proved to be more effective in improving senior high school students' HOTS on the human movement system topic compared to Discovery Learning implemented with a uniform scientific approach.

2. Average Scores at Each Higher Order Thinking Skills (HOTS) Cognitive Level

The differences in the average pretest and posttest scores across the three cognitive levels of Higher Order Thinking Skills (HOTS)—C4 (analyzing), C5 (evaluating), and C6 (creating)—for both the experimental and control classes are presented in Table 3. The results are expressed as the percentage of the maximum possible score obtained by students in each cognitive domain.

Table 3. Percentage of Average Scores for Each HOTS Cognitive Level

HOTS Cognitive Level	Maximum Score	Mean (Percentages)			
		Experimental Class		Control Class	
		Pretest	Posttest	Pretest	Posttest
C4 (Analyzing)	40	25,67%	70,75%	23,18%	58,00%
C5 (Evaluating)	15	13,56%	60,00%	6,66%	52,00%
C6 (Creating)	10	12,33%	66,00%	29,33%	49,7%

Based on the results summarized in Table 3, each HOTS cognitive level demonstrated greater improvement in the experimental class compared to the control class. The experimental group showed more optimal development across all cognitive levels, from analyzing (C4) to evaluating (C5) and creating (C6). These findings indicate that discovery learning integrated with differentiated instruction not only enhances overall student performance but also effectively develops higher-order cognitive processes at each level. Active student engagement in discovering concepts aligned with their learning preferences likely strengthened their cognitive processing, enabling deeper understanding and the ability to transfer knowledge to evaluative and creative tasks. Thus, instruction tailored to learners' characteristics proved more effective in developing HOTS than a uniform instructional approach.

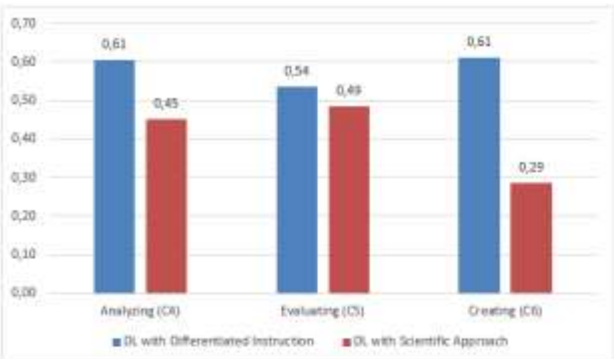

Figure 2. Comparison of N-Gain Across HOTS Cognitive Levels

The N-Gain analysis further confirms that the experimental class experienced consistently higher improvement across all HOTS levels compared to the control group. The differentiated Discovery Learning approach produced a stronger positive impact on students' analytical, evaluative, and creative thinking abilities. In contrast, the control class employing a scientific approach exhibited lower improvement, particularly in the creating (C6) domain, which represents the highest level of cognitive performance. These findings reinforce the notion that instructional design accommodating student learning profiles—particularly learning style preferences—contributes more effectively to comprehensive enhancement of HOTS.

3. Students' Higher Order Thinking Skills (HOTS) Categories

According to the International Center for the Assessment of Higher Order Thinking, students' Higher Order Thinking Skills (HOTS) can be classified into five proficiency categories. Based on the results displayed in Table 4, both groups demonstrated a shift toward higher levels of HOTS after the intervention. However, the improvement in the experimental class was more substantial, with a greater proportion of students transitioning from lower to moderate and high categories, including representation in the highest category. In contrast, the control class showed more limited progress, with some students remaining in the lower HOTS category.

Table 4. Frequency Distribution of Students' Higher Order Thinking Skills (HOTS) Categories

Category	Score Range	Number of Students (Percentages)			
		Control Class		Experimental Class	
		Pretest	Posttest	Pretest	Posttest
Excellent	81 ≤ score ≤ 100	0 (0,00%)	2 (6,66%)	0 (0,00%)	8 (26,66%)
Good	61 ≤ score ≤ 80	0 (0,00%)	12 (40,00%)	0 (0,00%)	13 (43,33%)
Fair	41 ≤ score ≤ 60	0 (0,00%)	8 (26,66%)	1 (3,33%)	6 (20,00%)
Poor	21 ≤ score ≤ 40	13 (43,33%)	8 (26,66%)	13 (43,33%)	3 (10,00%)
Very Poor	0 ≤ score ≤ 20	17 (56,66%)	0 (0,00%)	16 (53,33%)	0 (0,00%)
Number of Students		30		30	

These findings indicate that the discovery learning model, supported by differentiated instruction, was more effective in fostering students' advanced cognitive skills. The tailored learning approach enabled students to construct deeper conceptual understanding aligned with their individual learning characteristics, resulting in higher overall HOTS performance compared to the uniform instructional approach applied in the control class.

4. Learning Styles of Students in the Discovery Learning Group with Differentiated Instruction

Student learning styles were identified before the implementation of the Discovery Learning model with differentiated instruction in the experimental class. The study focused on three learning style types: visual, auditory, and kinesthetic.

Based on the identification results in Table 5, the findings indicate that students demonstrated diverse learning style characteristics, with a predominant tendency toward the visual learning style, followed by kinesthetic and auditory styles. This diversity served as a foundation for applying differentiated instruction, enabling the Discovery Learning model to be aligned with the individual learning needs of each student. Adjustments to learning media and activities based on identified learning styles are believed to enhance the effectiveness of the concept discovery process, which is a core feature of the Discovery Learning approach. These findings are consistent with Felder & Brent (2005), who emphasized that mapping student learning styles in instructional design can increase cognitive engagement and improve learning outcomes.

Table 5. Frequency of Student Learning Styles in Discovery Learning Groups with Differentiated Instruction

Learning Style	Number of Students	Percentage (%)
Visual	15	50%
Auditory	5	17%
Kinesthetic	10	33%

5. Results of Learning Implementation Observation

The results of the observation on learning implementation indicate that the learning process in both classes was carried out effectively in accordance with the instructional model applied. The implementation in the experimental class was more effective than in the control class, demonstrating that the Discovery Learning model with differentiated instruction can be successfully applied in classroom activities. This finding also reinforces the quality of the concept discovery process conducted by students in alignment with their individual learning characteristics.

Table 6. Implementation Observation Results

Class	Session			Mean	Category
	1	2	3		
Experimental	92,18%	92,69%	94,27%	93,04%	Excellent
Control	87,49%	83,85%	88,54%	86,62%	Excellent

6. Independent t-Test Results

The independent t-test was conducted to determine whether there was a significant effect between the two groups based on the variables examined. Based on the findings in Table 7, the significance value for the Gain Score in the two-tailed test was lower than 0.05 ($\alpha = 0.05$), indicating a significant difference between the two groups. These results demonstrate that the Gain Score of students in the experimental class implementing the Discovery Learning model with differentiated instruction differed significantly from that of the control class applying the Discovery Learning model with a scientific approach. Thus, it can be concluded that the use of differentiated instruction within the Discovery Learning framework had a significant influence on students' learning outcomes.

Table 7. Independent t-Test Results

	t	Significance (2-*tailed*)
Gain Score	3,179	0,002

7. Normalized Gain Results

The Normalized Gain test results indicate that the effectiveness of learning in both classes is in the fairly effective category. However, the improvement in learning outcomes in the experimental class is more pronounced compared to the control class. This suggests that the Discovery Learning model with a differentiated learning approach provides a greater boost to learning outcomes compared to learning in the control class.

Table 8. N-Gain Results

Class	Mean Gain Score	N-Gain	Category	Description
Experimental	46,73	0,5974	Medium	Fairly effective
Control	34,97	0,4470	Medium	Fairly effective

DISCUSSION

This study investigated the effect of the Discovery Learning model combined with differentiated instruction on students' Higher Order Thinking Skills (HOTS) in the human movement system topic for 11th-grade students. The research was driven by the need to strengthen students' HOTS in the 21st century, as many learners still struggle to think critically and creatively due to instructional practices that remain traditional and uniform.

Before treatment, the pretest scores indicated relatively equal initial ability between the experimental and control classes, with generally low results due to limited prior exposure to the topic and unfamiliarity with biological concepts such as skeletal structure, joint types, and muscle mechanisms. This aligns with Fatma & Listiawan (2025), who noted that low pretest scores typically occur when students have not received explicit instruction on the content.

After the intervention, students in the experimental class showed greater improvement in HOTS than those in the control class. Differentiated instruction supported students in learning according to their individual preferences and characteristics, leading to deeper conceptual understanding. This supports Tomlinson (2013) and Maeng (2017), who emphasized that differentiated learning enhances cognitive engagement and learning outcomes. Meanwhile, students in the control class, taught using Discovery Learning without differentiation, demonstrated improvements but at a lower magnitude, indicating limited accommodation for diverse learning needs.

The normalized gain (N-Gain) analysis showed that the experimental group achieved higher improvement levels, with average results approaching the high category, whereas the control group remained in the moderate category (Sholikhah et al., 2023; Wiguna et al., 2021). This confirms that integrating differentiation accelerates HOTS development more effectively than Discovery Learning alone. Furthermore, the increase across cognitive levels C4 (analyze), C5 (evaluate), and C6 (create) in the experimental class showed balanced growth. In contrast, the control class displayed minimal improvement in C6, suggesting that a scientific approach without differentiation struggles to foster creativity and innovation. This aligns with Rosyid et al. (2023), who reported that differentiated learning significantly enhances HOTS, especially creative thinking.

Categorization of HOTS scores further demonstrated that students in the experimental class achieved higher performance distributions, with many falling into good and very good categories, while the control group remained mostly in sufficient and low ranges. These findings support Rule & Lord (2003), who highlighted that differentiated strategies enable all learners, including lower-performing students, to reach higher cognitive levels.

The success of the experimental group was also supported by effective implementation of learning stages. Consistent application of Discovery Learning steps—stimulation, problem identification, data collection, data processing, verification, and conclusion—encouraged students to analyze information, verify concepts, and draw evidence-based conclusions (Ummiah & Fuadiyah, 2024; Wijiani et al., 2024). This aligns with Bruner's learning theory in Khasinah (2021), emphasizing active construction of knowledge through discovery as a foundation for higher reasoning skills.

Internal and external learning factors also contributed, including a supportive learning environment, differentiated materials, and active engagement consistent with Ubaidillah &

Darmawan (2025) and Dimas (2024). Meanwhile, the control class did not benefit from individualized support, which may have limited their cognitive engagement (Maeng, 2017). These results are consistent with recent studies indicating that Discovery Learning improves academic outcomes (Simbolon, 2023) and that integrating differentiation enhances science learning effectively (Laumarang et al., 2023; Primahesa et al., 2023). Thus, combining Discovery Learning with differentiated instruction is validated as a relevant strategy for developing HOTS in line with 21st-century learning demands.

Challenges remain in implementing differentiated learning, such as the need for teacher readiness and instructional resource support (Almujab, 2023; Zahra et al., 2025). Therefore, professional training and adequate school support systems are needed to ensure sustainable application. Overall, the findings confirm that Discovery Learning with differentiated instruction significantly enhances students' HOTS, fosters meaningful learning experiences, and supports the development of critical, creative, and independent thinkers capable of solving real-world problems and making informed decisions responsibly.

CONCLUSION

Based on the statistical analysis, the Discovery Learning model with differentiated instruction significantly improved senior high school students' Higher Order Thinking Skills (HOTS) on the musculoskeletal system topic compared to Discovery Learning without differentiation. This indicates that learning approaches that actively involve students and accommodate individual learning needs enhance deeper understanding and higher-level thinking. Teachers are encouraged to apply flexible differentiated strategies, and schools and policymakers should support their implementation in line with the Merdeka Curriculum. Future studies are recommended to vary learning activities and media to prevent student boredom, consider differences in learning pace in heterogeneous classes, and explore adaptive differentiation across other topics, levels, and variables such as motivation and learning autonomy.

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