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The Effect of Differentiated Approach in Inquiry-based Learning on Senior High School Students' Conceptual Understanding of Work and Energy Topic

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Abstract: This study aims to investigate the effect of the differentiated approach on high school students' conceptual understanding of the work and energy topic. The research method used is a quantitative method. Two classes of 10th graders in one of the Senior High Schools in the Tangerang districts were chosen to be research participants with cluster random sampling. Data collection was done with learning style questionnaire and conceptual understanding item with a reliability 0.73. The experimental class applied Inquiry-based Learning with differentiation, while the control class applied Inquiry-based Learning without differentiation. The results of the different tests of students' conceptual understanding after learning showed a significant difference in the understanding of students' concepts in the two classes. The effect size score showed a large effect of a differentiated approach on students' conceptual understanding. The analysis of the level of students' conceptual understanding for each subtopic showed the Law of Conservation of Mechanical Energy having the most students at irresponsiveness level, while the subtopics with the highest number of students at the understanding level was the work subtopic. The percentage of students who studied with a differentiated approach at the highest understanding level is more than students without a differentiated approach in all subtopics. Although the application of the differentiated approach had obstacles in online learning, the differentiated approach applied in Inquiry based Learning has a positive impact in facilitating the diversity of student learning styles.

Keywords: Conceptual Understanding; Differentiated Approach; Inquiry-based Learning

Introduction

Conceptual understanding is an important aspect of the learning process. In Indonesia, conceptual understanding is used as a reference in setting targets for student learning outcomes. Mills (2016) mentions conceptual understanding as a process. This process is related to students' ability to connect and organize knowledge, which will be useful in integrating theory and practice in daily life. When the relationship between theory and practice can be found, then learning will be more meaningful. Students' conceptual understanding affects the development of other abilities and skills. Conceptual understanding is connected with critical thinking skills (Ennis, 2018; Tiruneh et al., 2017), the ability to compose arguments (Demirbag & Gunel, 2014), reasoning abilities (Moore & Rubbo, 2012; Piraksa et al., 2014), and problem-solving abilities (Song, 2018). Therefore, students need to have a good understanding of concepts.

Students' conceptual understanding of the work and energy topic has been revealed. In this topic, students have difficulty in conceptual understanding. Analysis of conceptual understanding of students resulted that students' conceptual understanding is in the low category under 40% (Dienyati et al., 2020; Kassiavera et al., 2019). Students' misconceptions about several sub-topic of work and energy are also still high. The results of Maison et al (2020) and Samsudin et al (2021) researches explain that the sub-topic with high misconceptions is the Law of Conservation of Mechanical Energy and the work-energy theorem. Students' difficulties on this topic include: (1) applying the concept of work-energy to physics cases; (2)

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understanding work as a product of force and displacement; (3) understanding of work relationship with mechanical energy; (4) understanding the concept of potential energy on spring; and (5) applying the theory of work-energy (Muchoyimah et al., 2016; Pramesti et al., 2020; Rivaldo et al., 2020). The problem of understanding the concept on work and energy topic need to be followed up with proper learning.

Conceptual understanding developed through appropriate learning activities. Based on constructivist learning theory, students' understanding of concepts changes through active activities such as formulating and testing ideas, drawing conclusions, collecting and conveying new information (Kumar Shah, 2019; Santika & Herdi, 2020). Constructivism learning theory suggests experiential learning to build individual knowledge. Two learning models based on constructivism theory are problem based learning (PBL) and inquiry based learning (IBL). Inquiry based learning an active learning because not only transfers knowledge in the form of information through problems, but also raise knowledge through formulating the questions (Serafín et al., 2015). The activity of questioning a phenomenon and formulating the hypothesis that encourages students to think independently and propose ideas.

Inquiry-based learning is a learning model that has been shown to have a positive effect on students' conceptual understanding. Research by Herawati et al (2021) and Hermawati (2012) proves the positive effect of any type of IBL on students' conceptual understanding. In addition, IBL is also effective in increasing students' conceptual understanding at various levels of education (Hariyanto et al., 2019; Nasar & Kurniati, 2020; Sochibin et al., 2009). IBL involves the process of formulating hypotheses, joint experimentation as a social work practice, collecting and analysis of information, and final product creation (Mello et al., 2019; Xenofontos et al., 2020). The activities in IBL encourage students to actively build their knowledge through the investigation process. The application of IBL has a better impact on students' favorite topics (Borovay et al., 2019). Therefore, educators need to consider students' backgrounds to increase conceptual understanding in IBL.

The differentiated approach is a solution to facilitate differences in students' backgrounds with the aim of improving students' conceptual understanding. Differentiation is applied to overcoming the low participation of students due to different background (Lazonder et al., 2021), building student knowledge based on students' needs and capacities (Tulbure, 2013), exploiting students' strengths and improving students' weaknesses (Sternberg & Zhang, 2010). The differentiation given in heterogeneous class conditions will benefit students more. The application of the differentiated approach has proven to have a more positive effect on students' conceptual understanding compared to conventional learning classes (Blessing et al., 2021; Kado et al., 2021; Magableh & Abdullah, 2020). In addition to improving student learning outcomes, the application of differentiation also increases students' motivation to actively participate in the learning process. Currently, not many studies have tried to compare the effect of IBL with a differentiation approach with IBL without a differentiation approach.

This research comes from the awareness of the importance of building conceptual understanding to support the development of other skills. Inquiry-based learning was initiated as a solution to improve conceptual understanding in work and energy topics. In heterogeneous class conditions, Inquiry-based Learning may lead to differences between students. The difference may arise due to differences in student backgrounds such as the ability of students to process and interpret information. Therefore, a differentiated approach is applied in Inquiry-based learning to facilitate various student differences. This study aims to know the effect of the differentiated approach in Inquiry-based Learning on students' conceptual understanding. This research question is 'how is the difference in student's conceptual understanding in class with differentiation and without differentiation?' This question was answered by comparing students from IBL-Differentiation class and students from IBL class.

Method

The research method used is a quantitative method with a quasi-experimental design. The type of research is a pretest-posttest control group. The control class applied Inquiry-based Learning (IBL), while the experimental class applied IBL with a differentiated approach. The research design can be seen in Figure 1.

Table 1. Research Design

Subject	Pretest	Treatment	Posttest
Control	O1	X	O2
Experiment	O3	Y	O4

Description:
O1 = pretest in the experimental class
O2 = posttest in the experimental class
O3 = pretest in the control class
O4 = posttest in the control class
X = model IBL
Y = model IBL with differentiated approach

Before learning, the control class and the experimental class filled in the learning style questionnaire and conceptual understanding test (pretest). The results of the experimental class learning

style questionnaire were used to classify students into 3 groups, namely visual, auditory, and kinesthetic students. Each group in the experimental class consisted of students with the same learning style, while the control class group was arranged randomly. Each group in the control class learned IBL in the same way. The experimental class group learned adjusted by the results of the learning style test. The Differences in learning process can be seen from Figure 1. After learning, the two classes doing the conceptual understanding test (posttest).

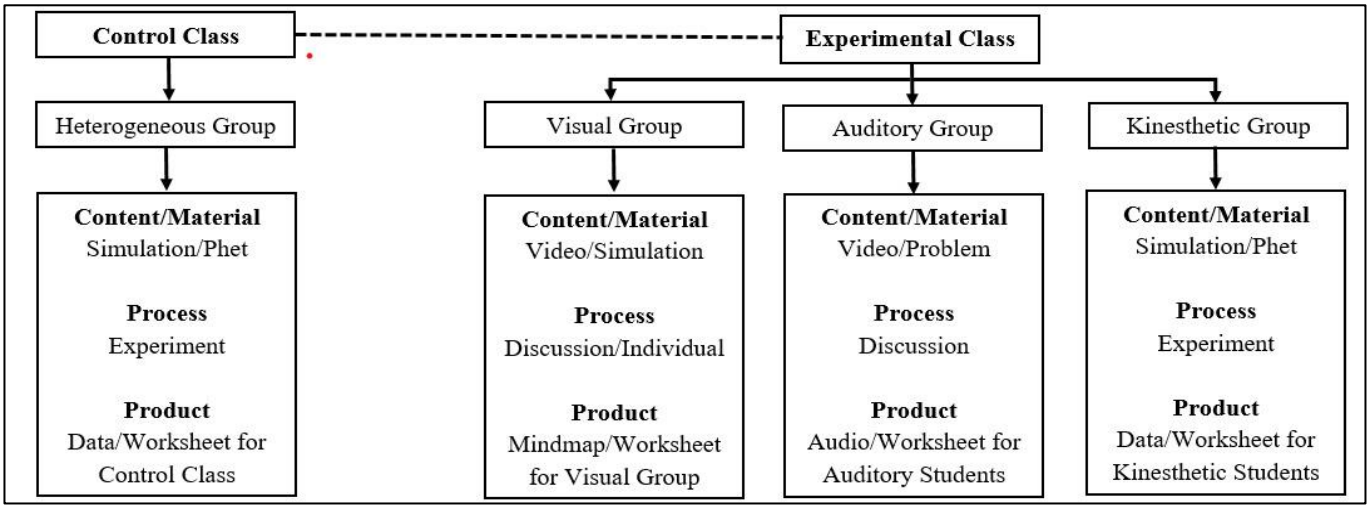

Figure 1. The Differences in Learning Process

The differences in the application of differentiation are seen in 3 aspects, namely content, process, and product. In Figure 1, it can be seen the differences in learning with differentiation in the experimental class and without differentiation in the control class. The content, process, and learning products of the control class are the same as those of the kinesthetic group in the experimental class. The visual and auditory groups in several meetings received the same content in the form of videos, but the process and learning products they made were not the same. The control class and the experimental class kinesthetic group are expected to be able to collect and analyze data to answer the hypothesis. Visual and auditory groups are expected to be able to understand information by compiling mind maps or making presentations in the form of audio.

The population of this study were all students of 10th grade in one of the Senior High Schools in Tangerang districts. The sample of this research is one class with IBL and one class with IBL-Differentiation. The experimental sample was selected using cluster random sampling technique. Two classes were selected, namely class X MIPA 1 as the control class and X MIPA 2 as the experimental class. The experimental class students were 29 students with a distribution of 6 male students and 23 female students. The control class consisted of 24 students with 7 male students and 17 female students.

The instruments in this study include conceptual understanding items and questionnaire. The questionnaire accessed through the akupintar.id platform that was used to investigate student learning styles. Quantitative data instruments in the form of conceptual understanding test items consisted of 5 questions that are accessed via google form. The item reliability score is 0.73 in the good category. The questions are adapted from work and energy topics in KD 3.7. Analyzing the concepts of energy, work (work), and energy changes, the Law of Conservation of Energy, and its application in everyday life. The first to fifth questions (Q1 to Q5) represent work, power, potential energy, kinetic energy, and the Law of Conservation of Mechanical Energy, respectively. The maximum score that can be obtained by students is 20.

Learning style analysis used to make study group data based on the test results of each student. The scoring method of quantitative data is arranged based on the level of students' conceptual understanding according to Akbaş et al., (2010) rubric which can be seen in Table 2.

Table 2. Level of Students' Conceptual Understanding

Level	Descriptive	Score
No Answer	No response	0
Irresponsiveness	Guess/No relationship with the topic	1
Misunderstanding	Assumptions not based on facts	2
Limited Understanding	Assumptions contain some scientific facts	3
Understanding	Assumptions contain all scientific facts	4

The scores of each group student were analyzed by descriptive statistics, Mann-Whitney U difference test, effect size, and N-gain to see the difference between the control and experimental classes. The score of each question was analyzed by descriptive statistics to see the level of students' conceptual understanding. The conceptual understanding score for each learning style was analyzed using the Mann Whitney U test to see the difference in understanding between learning styles in the two classes.

Result and Discussion

This research was conducted online, both data collection and treatment. The IBL model was applied in 3 synchronous meetings and 2 asynchronous meetings. The learning process and data collection are assisted by learning media zoom meeting, quizizz, and google form. In addition to providing different content, processes, and products between the experimental class and the control class, some IBL activities were also not available in the control class. The activities in IBL activities at synchronous meetings can be seen in Figure 2. The control class was not given the option to submit a written hypothesis in chat, study independently, and used formative assessment. The formative assessment given to the experimental class is self-assessment along with its feedback and discussion of the worksheet. The self-assessment is filled in by the student right after the lesson ends. In the self-assessment, students are given the freedom to ask questions or confirm the information they get at the meeting that day. Feedback on student questions is given at the next meeting orally and with the power point text. Discussion of worksheet and examples of questions related to topics that are considered difficult are described in PowerPoint form. Giving such feedback tends to benefit students with visual learning styles, as a result, many students in the kinesthetic and auditory groups did not respond positively.

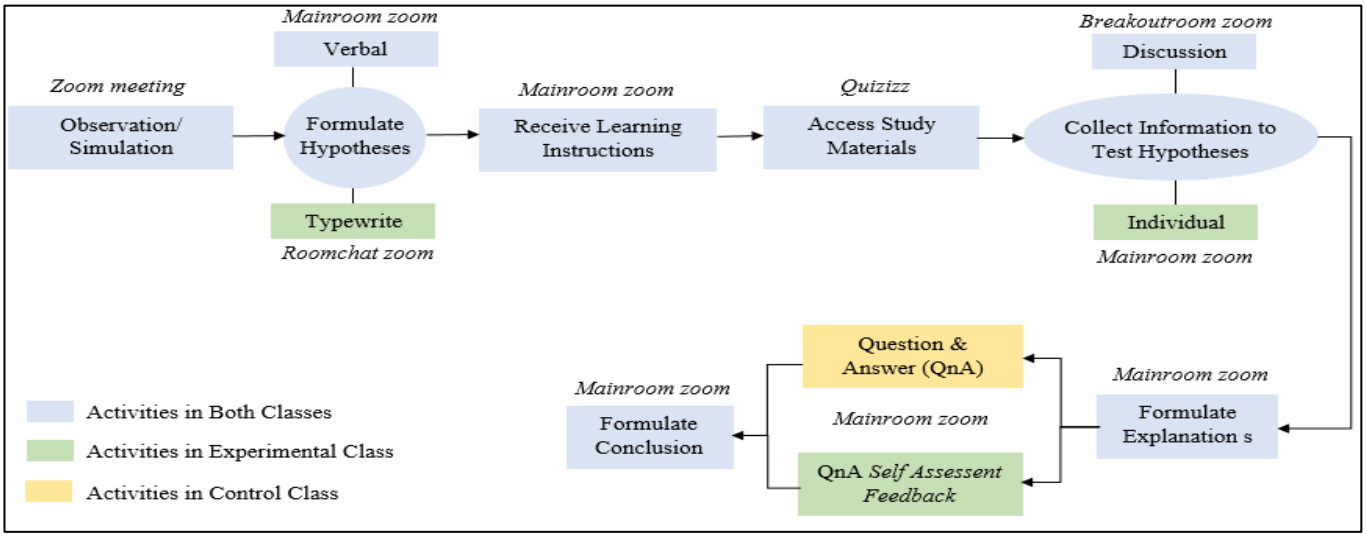

Figure 2. Activity Flowchart Inquiry-based Learning

The pretest and posttest questions were given separately from the learning meeting. The research sample was taken from students who submitted answers on time and followed the entire learning process. Students' questions and answers are submitted via google form. The summary of the pretest and posttest scores of the experimental class and control class is shown in Table 3.

Table 3. Summary of Conceptual Understanding Score

Class	Condition	N	Mean	Std. Dev
Control	Before learning	24	8.00	2.70
	After learning	24	11.08	2.12
Experimental	Before learning	29	6.72	2.39
	After learning	29	13.17	3.44

Before learning, the mean of the control class conceptual understanding score was higher than the experimental class. After learning, the experimental class was better than the control class. When compared with the maximum score that can be obtained by students, the mean score of the two classes before and after learning is still quite far. This difference is caused by the process of applying the differentiated approach which is less optimal during online learning. The results of the study by Idrus et al (2021) describe the challenges of implementing differentiation which is limited by time, facilities, and learning resources. However, some experimental class students were able to achieve scores close to the maximum score of 18. The scores for each question were used to classify students' level of conceptual understanding of the subtopics in KD 3.7.

The distribution of students' conceptual understanding levels after learning can be observed in Table 4.

Table 4. Percentage of Students' Conceptual Understanding Level

Conceptual Understanding Level	Percentage of Students' (%)	
	Control	Experimental
Q1. Work		
No Answer	0.00	0.00
Irresponsiveness	4.17	10.34
Misunderstanding	37.50	3.45
Limited Understanding	25.00	48.28
Understanding	33.33	38.93
Q2. Power		
No Answer	0.00	0.00
Irresponsiveness	12.50	10.34
Misunderstanding	16.67	0.00
Limited Understanding	66.67	82.76
Understanding	4.16	6.90
Q3. Potential energy		
No Answer	4.17	13.79
Irresponsiveness	16.67	17.24
Misunderstanding	41.67	3.45
Limited Understanding	8.33	20.69
Understanding	29.16	44.83
Q4. Kinetic energy		
No Answer	4.17	6.89
Irresponsiveness	41.67	27.59
Misunderstanding	12.50	3.45
Limited Understanding	37.50	27.59
Understanding	4.16	34.48
Q5. The Law of Conservation of Mechanical Energy		
No Answer	8.33	3.45
Irresponsiveness	75.00	55.17
Misunderstanding	8.33	3.45
Limited Understanding	4.17	17.24
Understanding	4.17	20.69

Table 4 shows the difference in the level of conceptual understanding of the two classes in each subtopic. At the level of understanding all subtopics, the percentage of students in the experimental class is higher than the control class. Experimental class students also dominated the limited understanding level on the subtopic of work, power, potential energy, and the Law of Conservation of Mechanical Energy. In all subtopics, the percentage of students in the control class with a misunderstanding level was higher than in the experimental class. These results indicate that IBL without differentiation still produces a fairly high level of misunderstanding. The percentage of control class students in the irresponsiveness level of power, kinetic energy, and the Law of Conservation of Energy is higher than in the experimental class, while the work and potential energy subtopic are lower than the experimental class. No answer shows that students' conceptual understanding cannot be known for certain because there are no responses or explanations from students.

The work subtopic is measured by the first question (Q1) with the aim of "Connecting the concepts of force and work into a simple equation." In this question, there are no students who do not answer the question so the level of students' conceptual understanding can be known entirely. It can be seen in Table 4 that most of the control class students were at the level of misunderstanding, while most of the experimental class students were at the limited understanding level. The student's answer in Q1 is only a direct comparison of the known variables without paying attention to the relationship between these variables.

The second question (Q2) on this research item is intended to measure students' ability to "Connecting the concepts of power and work in the form of simple equations." The level of conceptual understanding in this subtopic can be fully known because there are no empty answers. Most of the control and experimental class students were at a limited understanding level. Only a small number of students can reach an understanding level. Research by Muchoyimah et al (2020) shows that power is the subtopic that students answer the most incorrectly compared to other subtopics in the topic of work and energy. However, none of the experimental class students were at the level of misunderstanding. These results prove that the differentiated approach in IBL has succeeded in reducing the number of students' misunderstandings more than IBL without differentiation in this subtopic.

The measurement of understanding in the potential energy subtopic is represented by the third question (Q3) with the aim of "Showing the relationship between work with potential energy." In this subtopic, most of the control class students are still at the misunderstanding level, while most of the experimental class students are already at the understanding level. However, as many as 13.79% of the experimental class students and 4.17% of the control class students could not detect the level of understanding in this subtopic because there were no answers. Errors that generally occur in control class students are because they do not understand the mathematical strategy to calculate the potential energy of a spring.

The kinetic energy subtopic is measured through the fourth item (Q4) which is prepared with the aim of "Showing the relationship between work and kinetic energy." The number of experimental class students is mostly at the understanding level, while the control class students are mostly at the irresponsiveness level. Students' difficulties in understanding the concept of kinetic energy in the case of the work-kinetic energy theorem were also detected in previous studies (Muchoyimah et al., 2016, 2020). The level of

irresponsiveness of control class students can be seen from the number of students who answered by describing conservative and non-conservative forces. This answer does not quite relate to the question of the work-kinetic energy theorem. The number of experimental class students at the misunderstanding level is smaller than the number of students whose concept understanding ability cannot be detected.

The Law of Conservation of Energy is discussed in the fifth question (Q5) with the aim of measuring students' ability to "Apply the principle of the Law of Conservation of Mechanical Energy in life." More than 50% of the experimental and control class students are still at irresponsiveness level. The low understanding of the subtopic of the Law of Conservation of Mechanical Energy has also been studied before. The results of research by Maison et al (2020) and Samsudin et al (2021) state that a low understanding of the Law of Conservation of Mechanical Energy reaches more than 40% of the total number of students. This number is in the second order of subtopic with the most misconceptions experienced by students. The experimental class students at an understanding level were more than the control class, however, many control class students could not detect the level of conceptual understanding because they did not answer the questions.

The difference test with Mann Whitney U was used to see the difference in conceptual understanding between IBL classes with differentiation and without differentiation. The control and experimental class pretest data were analyzed to see whether or not there was a difference in the students' initial conceptual understanding. The posttest data of the two classes was used to prove whether or not there were differences in the conceptual understanding of students who applied IBL and students who applied IBL-Differentiation. The results of the different tests and their interpretations can be seen in Table 5.

Table 5. Results of the Differences in Students' Conceptual Understanding

Condition	Sig	Interpretation
Before Learning	0.138	No Differences
After Learning	0.025	Differences

The results of the different tests showed that the conceptual understanding of the students in the two classes was the same before the lesson was given. After learning, the two classes have different conceptual understanding. The results of the posttest effect size calculation is 0,98. This value shows the large effect of differentiated approach on students' conceptual understanding. Research by Blessing et al., (2021); Kado et al., (2021); Magableh & Abdullah, (2020) supports these results by proving that there is a significant difference in classroom learning outcomes with and without differentiation. Although not many studies have tried to compare IBL-Differentiation with IBL, these previous studies have proven the effect of the differentiation approach on students' conceptual understanding. In more detail, the differences in students' conceptual understanding can be seen from the N-gains in Table 6.

Table 6. N-Gain and Differences of Learning Style Group

Learning Styles	N-Gain		The Different Tests	
	Control Class	Experimental Class	Sig	Interpretation
Visual	0.182 (Low)	0.547 (Medium)	0.001	Differences
Kinesthetic	0.302 (Medium)	0.400 (Medium)	0.496	No Differences
Auditory	0.133 (Low)	0.233 (Low)	0.564	No Differences

The results of the N-gain analysis showed that the increase in conceptual understanding of students in the visual and kinesthetic learning style group in the experimental class was in the medium category. The difference in the N-gain category was seen between the visual group of the experimental class and the control class. Overall, the N-gain number of the experimental class was higher than the control class. The application of IBL has been proven to result in an increase in understanding of concepts that is better than learning with conventional models (Hariyanto et al., 2019; Putra & Masruri, 2019; Yusrizal et al., 2017). In addition, previous research also showed that the N-gain of students who applied IBL-Differentiation was in the moderate category (Rais et al., 2021). Although there are not many studies that apply IBL-Differentiation in physics learning, the data proves that the increase in conceptual understanding of students who apply IBL-Differentiation is higher than IBL without differentiation. The application of a differentiated approach based on learning styles is considered to be more motivating and improve students' academic achievement because it can facilitate their diversity (Ariani et al., 2018).

The auditory group experienced an improvement in the low category in both classes. The low improvement in the auditory group compared to other groups is contrary to the research of Malacapay (2019) which proves that the learning outcomes of the auditory group are superior to other groups in differentiation

learning. These results are also not in line with the research of Ariani et al., (2018) which explains the highest increase experienced by the kinesthetic group in the application of IBL-Differentiation. The discrepancy between the results of this study and the results of this study is thought to arise because the instructions and feedback tend to be more favorable to the visual group during online learning. It is known that providing quality and effective feedback can increase student learning speed (Box, 2015; Taras, 2010). It can be seen from the students' cognitive responses in the form of thoughts (Tomlinson & Moon, 2013). However, students in the auditory group tend not to respond to the feedback given.

Despite having the same background and learning method, in fact, the increase in the score of the kinesthetic group of the experimental class was higher than the increase in the score of the kinesthetic group of the control class. This difference may be caused by the lack of options for control class students to study independently or in groups. All control class students worked in groups and most of them felt uncomfortable. The discomfort of controlling class students in groups can be seen from the number of student complaints when the teacher asks students to the group. The results of the analysis of students' multiple intelligences, it is known that 71% of control class students have dominant intrapersonal intelligence. Individuals with intrapersonal intelligence have the characteristics of working independently and easily understanding something by finding it themselves (Gardner, 2006). Therefore, apart from the additional feedback for the experimental class, the absence of differentiation in the information-gathering process may be the cause of this discrepancy.

The differentiated approach based on learning style/student learning profile has been tried to prove its effect by several previous studies. Research Blessing et al (2021) shows that there is a significant difference in students' conceptual understanding between classes that apply differentiation of learning styles with conventional ones. Other studies also explain that there is no effect of differences in learning styles on student learning outcomes who apply differentiation learning (Malacapay, 2019). However, the provision of learning style differentiation is an attempt to equalize the cognitive load of students in achieving the same goal. Based on this discussion, it can be seen that the differentiated approach has an effect on student learning outcomes regardless of the differentiation base used.

Conclusion

The aim of this study is to investigate the effect of the differentiated approach on students' conceptual understanding. The results of a data analysis showed that there was a significant difference between students who applied IBL-Differentiation and students who applied IBL without differentiation. The effect size score showed a large impact of the differentiated approach. These results are supported by the N-gain scores of students in the class with the differentiated approach which is in the medium category, while students in the class without the differentiated approach improve in the low category. Based on learning styles, the different tests for auditory and kinesthetic learning styles of the two classes showed no difference in conceptual understanding between groups of student learning styles. However, the improvement in the auditory group in both classes was only in the low category. The differentiated approach in IBL can be a solution to facilitate the diversity of student learning styles. The results of this study are expected to be a reference for further research regarding the differentiated approach. Further research is expected to be able to make student differentiation with reference to more than one student's background. In addition, differentiation should also include feedback and learning instructions in the classroom.

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