Implementing Differentiated Learning Using the Problem-Based Learning Model to Stimulate Students' Problem-Solving Skills

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ABSTRACT
The lack of implementation of differentiated learning causes teachers to be unable to accommodate students' various learning styles, which in turn reduces students' problem-solving abilities. This research aims to determine the influence of implementing content and process differentiation learning using the PBL model on improving problem-solving skills for each learning style of students and to identify the problem-solving skills that may arise from differences in learning styles. The research design used was a one-group pretest-posttest design. The research sample consisted of students in classes X-1 and X-2 at Public Senior High School Bandar Lampung in the academic year 2023/2024. The data collection method is through tests using pretest and posttest questions with indicators of problem-solving ability, and data analysis using paired difference tests (paired sample t-test) and one way ANOVA. The results of the study indicated a difference between the pretest and posttest scores of the students, where the posttest scores were higher than the pretest scores, indicating an improvement in students' problem-solving skills. The N-gain value was greater than 0.05, indicating no difference in problem-solving skills.

INTRODUCTION
Education in the 21st century demands mastering various important skills for individuals. One of its aims is to prepare students to acquire the skills needed in the 21st century to achieve success. The learning skills in the 21st century are crucial for achieving a better future for students. In this century, there is a demand in schools to have critical thinking, creative thinking, collaboration, and communication skills, which enable students to work in groups and solve problems (Maulidiah et al., 2023).

Problem-solving skills are a learning process that encourages students to actively participate and effectively respond to questions (Hartinah et al., 2019). In other words, problem-solving skills can help students overcome difficulties that arise in the problem-solving process. Problem-solving skills are essential for achieving success in physics learning, as they play a significant role in obtaining better achievements (Firmansyah et al., 2022). Problem-based learning aims to enhance higher-order thinking skills, develop knowledge, independence, and self-confidence when students are confronted with a problem in the learning process (Arends, 2012).

Currently, the problem-solving skills possessed by students are still low, as the teaching methods used are still predominantly lecture-based and have not fully implemented the appropriate learning models. A learning framework intricately associated with problem-solving proficiency is the
Problem-Based Learning (PBL) model. This model is employed to address issues pertinent to daily life, facilitating a more accessible comprehension and resolution of problems for students. Theoretically, the PBL model encourages students to actively solve real problems using the knowledge and skills they have learned (Firmansyah et al., 2022).

Based on the research conducted by Tyas (2017), there are difficulties in implementing the PBL model due to the heterogeneity, including students' learning styles, where students do not receive the desired learning needs. One of the heterogeneities among students is learning style. These diverse learning styles must be accommodated with various teaching methods, which can be interpreted as differentiated learning. Differentiated learning is an approach used by teachers to meet the needs of students. The study by Nurmayani et al. (2016) regarding the impact of learning styles on the application of PBL revealed noteworthy findings, which suggest a correlation between the PBL learning model and students' learning outcomes based on their learning styles.

Based on the interviews conducted by the researcher with the physics teacher of 10th grade at Public Senior High School 13 Bandar Lampung, it is revealed that the students still have low problem-solving skills. This is because the teaching method still relies heavily on lecturing and has not fully implemented the appropriate instructional models. The problem-solving skills possessed by students at Public Senior High School 13 Bandar Lampung are still lacking due to the lack of implementation of differentiated learning, which fails to accommodate various learning styles of students. Therefore, this study was conducted to investigate the influence of implementing differentiated content and process learning using the PBL model on enhancing problem-solving skills for each learning style of students. Furthermore, it aimed to identify the problem-solving skills that may arise from differences in learning styles.

In this study, the researcher used content and process differentiation. Content differentiation learning in this study involves using instructional materials tailored to students' learning styles. These activities should be related to what the students are learning and meaningful as learning experiences. According to Alhafiz (2022), process differentiation involves how students process ideas and information, understand the material, and how that understanding influences their learning choices. Activities that students can engage in include listening for auditory learners, observing for visual learners, and conducting experiments for kinesthetic learners.

Darmuki and Hariyadi's (2019) learning styles involve how students absorb and process information. Each student has unique personal characteristics that differ from other students. Individual students exhibit variations in performance levels, pace of learning, and preferred learning styles. These distinctions in learning styles signify the most effective way students assimilate information during the learning process (Papilaya & Huliselan, 2016). Visual, auditory, and kinesthetic learning styles will affect students' learning outcomes or achievements (Febriana, 2020). This study employed the problem-based learning model.

Problem-based learning is a set of approaches to empower students to become independent individuals capable of facing various problems (Wijaya, 2021). The problem-solving process in this method trains students to become skilled at solving problems collaboratively and individually through an investigative approach. In problem-based learning, students are required to seek as much information as possible, analyze it, and find appropriate solutions (Hudha et al., 2017). The main goal of the PBL model is to stimulate students' thinking skills.

Problem-solving is the process of achieving goals while overcoming various obstacles. Problem-solving requires multiple thinking skills, including observing, drawing conclusions, describing, reporting, and generalizing based on collected and processed information (Nur, 2019). The concept of physics is closely related to everyday life and is problem-based. One of the goals of physics education is to emphasize problem-solving skills (Docktor et al., 2015). The ability to solve problems is essential for students in physics learning. Students must be able to identify, determine, and solve problems using logic, lateral thinking, and creativity to become proficient in solving physics problems (Hudha et al., 2021).
RESEARCH METHODS

Research Approach
This research constitutes a quantitative experimental investigation employing a quasi-experimental approach with a one-group pretest-posttest design. Participants were initially categorized based on their learning styles, namely visual, auditory, and kinesthetic. Before implementing instructional interventions, a pretest was administered to each group. Subsequently, differentiated instruction utilizing the Problem-Based Learning (PBL) model was introduced, followed by the administration of a posttest.

Research Participants
The population of this study consists of all 10th-grade students at Public Senior High School Bandar Lampung, comprising seven classes in the odd semester of the 2023/2024 academic year. This study takes one class as the research sample, 10th-grade 1 and 10th-grade 2, which will receive differentiated learning treatment. The sample used in this study is purposive sampling.

Research Instruments
Diagnostic assessment is an assessment given to students at the beginning of learning. This test is administered to determine the learning styles of students. The test sheet consists of 12 statements representing 3 types of learning styles.

The test sheet is used to measure problem-solving skills in students. This instrument is used during the pretest and posttest with essay questions consisting of 2 problem cases, each with four questions following the problem-solving skill indicators. The test sheet is used to measure students’ problem-solving skills, the indicators of understanding, planning, solving, and checking (Agsya et al., 2019). This instrument is used during the pretest and posttest, consisting of essay questions with two problem cases following the problem-solving skill indicators. The research instrument has been subjected to validity and reliability tests.

Data Collection
The data collection technique in this research employs a quantitative method. Before data collection for the pretest, the researcher distributed a diagnostic assessment test to determine students' learning styles and then grouped them based on them. The pretest and posttest instruments were used with indicators based on students' problem-solving skills. The test sheet measures students' problem-solving skills, understanding, planning, solving, and checking indicators.

The implementation phase was carried out by administering a learning style questionnaire to determine the groups based on their learning styles. Then, the students were given a pretest to assess their initial problem-solving skills. After the pretest, the researcher grouped the students according to their learning styles, and then they were subjected to differentiated learning treatment using the PBL model. The learning activities were divided into two sessions. In the first session, the students discussed the causes of global warming, and in the second session, they discussed the impacts of global warming. For further details, refer to Table 1.

| Table 1. Student activities based on learning style groups using the PBL model. |
|-------------------------------------------------|---------------|-------------------------------------------------|
| **PBL** | **Learning style** | **Activities** |
| Orienting the students to the problem | Visual | Identifying the phenomenon of global warming through the presentation of an article. In activity 1, students analyze an article containing information about extreme temperatures. In activity 2, students analyze information about climate change and ecosystem disruption caused by natural disasters. |
| | Auditori | Identifying the phenomenon of global warming through the presentation of a video. In activity 1, students analyze the content of a video about extreme temperatures. In activity 2, students analyze the content of a video about climate change and ecosystem disruption caused by natural disasters. |
Fase 2: Organizing the students.

<table>
<thead>
<tr>
<th>PBL</th>
<th>Learning style</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kinesthetic</td>
<td>Identifying the phenomenon of global warming through observation. In activity 1, students conduct observations in a closed room. In activity 2, students conduct observations under a tree.</td>
</tr>
<tr>
<td></td>
<td>Visual</td>
<td>Providing literature sources to solve the problem.</td>
</tr>
<tr>
<td></td>
<td>Auditori</td>
<td>Providing supporting applications, such as YouTube, to solve the problem.</td>
</tr>
<tr>
<td></td>
<td>Kinesthetic</td>
<td>Providing laboratory tools and materials to solve the problem.</td>
</tr>
</tbody>
</table>

Fase 3: Assisting in conducting group investigations

<table>
<thead>
<tr>
<th>PBL</th>
<th>Learning style</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Visual</td>
<td>Investigating with data collection from articles.</td>
</tr>
<tr>
<td></td>
<td>Auditori</td>
<td>Investigating with data collection from videos.</td>
</tr>
<tr>
<td></td>
<td>Kinesthetic</td>
<td>Investigating with data collection through practical experiments.</td>
</tr>
</tbody>
</table>

After the treatment, the students were given a posttest to determine whether their learning needs and problem-solving skills improved.

Data Analysis

a. N-gain Score Test

The data collection technique is an effort to obtain supporting data to achieve the research objectives. The data collection methods employed in this study are as follows:

\[
N - Gain = \frac{Post\ test\ score - Pre\ test\ score}{100 - Pre\ Test\ score}
\]

The N-Gain value criteria with progress categories are as follows:

<table>
<thead>
<tr>
<th>N-Gain Score</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>( N - Gain \geq 0.70 )</td>
<td>High</td>
</tr>
<tr>
<td>( 0.70 &gt; N - Gain &gt; 0.3 )</td>
<td>Medium</td>
</tr>
<tr>
<td>( N - Gain \leq 0.3 )</td>
<td>Low</td>
</tr>
</tbody>
</table>

The categories for obtaining an interpretation of N-gain’s effectiveness in percent are stated in Table 3.

<table>
<thead>
<tr>
<th>Percentage (%)</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 40</td>
<td>Ineffective</td>
</tr>
<tr>
<td>40 – 55</td>
<td>Less effective</td>
</tr>
<tr>
<td>56 – 75</td>
<td>Effective enough</td>
</tr>
<tr>
<td>&gt; 76</td>
<td>Effective</td>
</tr>
</tbody>
</table>

b. Normality Test

The Normality test used to determine whether the collected data is normally distributed or taken from a normal population. It was conducted on each learning style group’s pretest, posttest, and N-gain results. Data was collected using the Kolmogorov-Smirnov method in SPSS 26, which can be calculated based on significance and probability values (Suyatna, 2017).

Hypothesis formulation

\( H_0 \): Data is normally distributed

\( H_1 \): Data is not normally distributed

Test criteria

\( H_0 \) is rejected if the Sig. value or probability value is < 0.05,
c. Homogeneity test
The Homogeneity test determines the equality of variances between two or more data distributions. According to Triyono (2013), decision-making criteria are as follows:

a. If the Sig. value < 0.05, the samples are not homogeneous.
b. If the Sig. value > 0.05, the samples are homogeneous.

d. Paired Sample T-Test
The paired sample t-test aims to determine the difference between paired pretest and posttest values when the data is normally distributed. The paired sample t-test is conducted using SPSS 26.0.

Hypothesis for Paired Sample T-Test

\( H_0: \) There is no significant difference in problem-solving skill improvement among students with visual, auditory, and kinesthetic learning styles after differentiated learning using the PBL model.

\( H_1: \) There is a significant difference in problem-solving skill improvement among students with visual, auditory, and kinesthetic learning styles after differentiated learning using the PBL model.

Test criteria
If Sig(2-tailed) < 0.05, \( H_0 \) is rejected and \( H_1 \) is accepted.

e. One Way Anova
Anova test is used to determine whether there is a difference in N-gain results (Suyatna, 2017). Normal distribution and homogeneity tests are performed before conducting the One Way ANOVA test.

Hypothesis for One Way Anova

\( H_0: \) There is no significant difference in problem-solving skills among students with visual, auditory, and kinesthetic learning styles after differentiated learning using the PBL model.

\( H_1: \) There is a difference in problem-solving skills among students with visual, auditory, and kinesthetic learning styles after differentiated learning using the PBL model.

Test Criteria
The criteria for decision-making in the One Way Anova test, according to Suyatna (2017) are to reject \( H_0 \) if \( \text{sig.} < \alpha \), where \( \alpha = 0.05 \) and accept \( H_0 \) if \( \text{sig.} \geq \alpha \), where \( \alpha = 0.05 \).

RESULTS AND DISCUSSION

Results
This research was conducted to determine the improvement of problem-solving skills among students in global warming. The essay test technique was used to measure the students' problem-solving skills. The treatment given was the implementation of differentiated learning using the PBL model.

Table 4. Data and normal distribution test results of pretest and posttest.

<table>
<thead>
<tr>
<th>Score acquisition</th>
<th>Visual</th>
<th>Auditory</th>
<th>Kinesthetic</th>
</tr>
</thead>
<tbody>
<tr>
<td>The average value of the pretest</td>
<td>50.9</td>
<td>56</td>
<td>54.1</td>
</tr>
<tr>
<td>The average value of the posttest</td>
<td>82.1</td>
<td>83.2</td>
<td>82.7</td>
</tr>
<tr>
<td>Sig. pretest</td>
<td>0.137</td>
<td>0.200</td>
<td>0.157</td>
</tr>
<tr>
<td>Sig. posttest</td>
<td>0.072</td>
<td>0.200</td>
<td>0.140</td>
</tr>
</tbody>
</table>

Table 4 presents the data on the problem-solving skills of the students. In each group, the mean scores of students were lower in the pretest than in the posttest, suggesting a variance and enhancement in their problem-solving skills. The disparity between pretest and posttest data within
each learning style group was examined using paired sample t-tests for problem-solving skills, with the results presented in Table 5.

**Table 5. The results of the paired sample t-test for problem-solving skills**

<table>
<thead>
<tr>
<th>Group</th>
<th>Paired Difference Mean</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest-posttest visual</td>
<td>-31.2308</td>
<td>0.000</td>
</tr>
<tr>
<td>Pretest-posttest auditori</td>
<td>-27.2500</td>
<td>0.000</td>
</tr>
<tr>
<td>Pretest-posttest kinesthetic</td>
<td>-28.941</td>
<td>0.000</td>
</tr>
</tbody>
</table>

The table examination reveals that the two-tailed p-values for both pretest and posttest are below 0.05. This outcome leads to the acceptance of H₁, signifying a notable distinction between the pretest and posttest within each learning style group. The pretest scores are lower than the posttest scores, suggesting an improvement in the initial problem-solving skills of the students to their final problem-solving skills based on their learning style group.

A homogeneity test was employed to assess the uniformity of the provided samples, and the outcomes are presented in Table 6.

**Table 6. Homogeneity test results of n-gain visual, auditori, and kinesthetic.**

<table>
<thead>
<tr>
<th>Levene Statistic</th>
<th>df1</th>
<th>df2</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.509</td>
<td>2</td>
<td>43</td>
<td>.242</td>
</tr>
</tbody>
</table>

Table 6 shows that the p-value is more significant than 0.05, which means that H₀ is accepted, indicating that the learning outcomes of the visual, auditory, and kinesthetic groups have the same variance or are homogenous. The hypothesis test results using one-way ANOVA can be seen in Table 7.

**Table 7. Hypothesis test results using One-Way ANOVA.**

<table>
<thead>
<tr>
<th>Sum of Squares</th>
<th>Df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>.001</td>
<td>2</td>
<td>.000</td>
<td>.004</td>
<td>.996</td>
</tr>
</tbody>
</table>

From Table 7, it can be observed that the p-value for the hypothesis test is 0.996, which is greater than 0.05. Therefore, it can be concluded that H₀ is accepted and H₁ is rejected, indicating no difference in problem-solving skills among the visual, auditory, and kinesthetic groups.

The students' problem-solving skills showed improvement after the treatment, as seen in the pretest and posttest scores of each learning style group, which can be further observed in Figure 1.

**Figure 1.** Graph of pretest and posttest scores based on learning style

Figure 1 shows that the pretest scores were higher than the posttest scores in each learning style group. Applying the paired sample t-test for hypothesis testing yielded a significance value below 0.05. Consequently, the acceptance of H₀ suggests a noteworthy enhancement between the pretest and posttest scores within each learning style group, with a confidence level of 95%.

This study aimed to ascertain the comparability of advancements in problem-solving skills among students exhibiting visual, auditory, and kinesthetic learning styles within a differentiated...
learning framework. Participants were categorized into groups corresponding to visual, auditory, and kinesthetic learning styles.

Based on the N-gain analysis results from the above graph regarding the differences in problem-solving skills due to learning style variances, there was no significant difference in N-gain values. This was observed in students with a visual learning style, with an average N-gain of 0.62. The auditory learning style has an average N-gain of 0.64, and the kinesthetic learning style has an average N-gain of 0.62.

Discussions

This research applied differentiated learning using the PBL model by grouping students based on their learning styles. Grouping based on learning styles is one of the efforts to meet the learning needs of students.

The first group is the visual group, which prefers writing and receiving information more quickly through reading rather than listening. Students with visual learning styles tend to process information related to visual perception, and they prefer reading over listening (Rahmawati & Gumiandari, 2021). The learning activities conducted by the visual group are observable in Figure 3.

In the problem orientation stage, students with a visual learning style analyze phenomena through articles and collect data from those articles. The second group, known as the auditory group, prefers speaking over writing and receives information more quickly through listening rather than reading. Students with an auditory learning style tend to receive information related to the sense of hearing, and they find it easier to memorize and remember information obtained through listening (Rahmawati & Gumiandari, 2021). The learning activities conducted by the auditory group are observable in Figure 4.
In the problem orientation stage, students with an auditory learning style analyze phenomena through videos and collect data from those videos. The third group, known as the kinesthetic group, prefers performing practical demonstrations over writing and quickly receives information through bodily movements such as touch or action. Students with a kinesthetic learning style prioritize body movements to remember information (Rahmawati & Gumiandari, 2021). The learning activities conducted by the kinesthetic group are observable in Figure 5.

In the problem orientation stage, students with a kinesthetic learning style observe and collect data through practical activities. Through differentiated learning by providing teaching materials and learning activities that align with students' learning styles, they become more engaged, motivated, and able to optimize their potential to understand and solve problems. In the learning activities of students with diverse learning needs, the researcher implements the learning process according to their individual learning needs based on their learning styles. The researcher accommodates all the learning needs of the students, starting from e-books supporting videos, and practical tools and materials. The researcher continuously monitors the progress in each learning process.

During the learning process, challenges arise, such as maintaining a conducive learning environment for the students. Some students may still struggle to grasp the learning materials, so the researcher repeatedly explains the process of working with e-Student Worksheet. Additionally, the researcher ensures that all students understand the given learning materials by providing extra supervision throughout the learning process.

Consistent with Laia et al.’s (2022) study, the findings support that the adoption of differentiated learning aligns with meeting the diverse learning requirements of students. Sarie's (2022) study on differentiated learning using the PBL model in elementary school students, considering their learning styles, found that students were enthusiastic in participating throughout the learning process, and differentiated learning was able to meet their learning needs.

The implementation of the PBL model necessitates active student engagement in the process of problem-solving. They need to collaborate in groups to gather relevant information and data. In this process, they learn to organize information and make decisions based on available evidence. The PBL model also encourages collaboration and communication among students. They work together to find
the best solutions, share ideas, and provide feedback to each other is consistent with the research conducted by Sarie (2022), which stated that learning using the PBL model provides flexibility for students, improving their problem-solving skills. This flexibility helps students develop initiative in problem-solving. Therefore, using the PBL model can be an effective learning method to enhance students' problem-solving skills.

CONCLUSION
Based on the results and discussion, it can be concluded the implementation of differentiated content and process learning using the PBL model can stimulate problem-solving skills of students for each learning style difference, as shown by the increase in average problem-solving skills among visual, auditory, and kinesthetic learners, with an average N-gain for the visual group at 0.62, auditory at 0.64, and kinesthetic at 0.62, categorized as moderate.

Differentiated instruction can meet students’ learning needs. Teachers are advised to approach teaching using differentiated instruction by grouping students based on their learning styles so that students can collaborate with peers who have similar criteria, fostering enthusiasm and activity throughout the learning process. One limitation of this study is the lack of a greenhouse in the school, prompting the researcher to create a simple laboratory tool that simulates the greenhouse effect phenomenon.

It is recommended that future research extends to the product component so that students’ problem-solving skills can be stimulated more effectively. This study only utilized the experimental class; therefore, for future research, it is advisable to compare the effectiveness of learning using the PBL model with differentiated learning using the PBL model.

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References


