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Effectiveness of the PjBL Model Assisted by Differentiated Teaching Materials to Improve Students' Cognitive and Creative Thinking Skills

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Abstract: The purpose of this study was to measure the effectiveness of the PjBL model assisted by differentiated teaching materials in improving students' cognition and creativity. This research aims to evaluate the effectiveness of the Project Based Learning (PjBL) model assisted by differentiated teaching materials in improving students' cognitive abilities and creative thinking skills on temperature and heat material. This research uses a quasi-experimental method with a pretest-posttest control group design. The research sample consisted of two classes in one high school in Indonesia, with one class as an experimental group using PjBL assisted by differentiated teaching materials, and one class as a control group using conventional learning methods. Data was collected through cognitive ability tests, creative thinking skills tests, student motivation and engagement questionnaires, as well as interviews with teachers and students. The research results show that the PjBL model assisted by differentiated teaching materials significantly improves students' cognitive abilities and creative thinking skills compared to conventional learning methods. In addition, students in the experimental group also showed higher motivation and involvement in the learning process. Interviews with teachers and students revealed that the learning experience using this model was very positive, with students feeling more engaged and teachers seeing improvements in student learning outcomes.

Keywords: Education; Learning method; Skills

Introduction

Education is the main pillar in the development of a nation. Quality education is able to produce the next generation who are not only intellectually intelligent but also have creative and innovative thinking skills. One of the main challenges in today's world of education is how to develop effective learning strategies to develop students' potential optimally (Purwanto et al., 2023; Tyas et al., 2021). Learning models that only focus on cognitive aspects without paying attention to aspects of creative thinking skills are often unable to face the challenges of an increasingly complex era (Akour et al., 2022; Meyer et al., 2020).

In this context, the project-based learning model or Project Based Learning (PjBL) has emerged as a promising alternative. PjBL is a learning method that puts students at the center of learning through their involvement in real-life relevant projects (Almulla, 2020; Ngereja et al., 2020; Wahbeh et al., 2021). This model encourages students to actively seek information, solve problems, and produce tangible products. PjBL not only develops students' cognitive abilities but also trains their creative, collaborative, and communication skills (Kurniahtunnisa et al., 2023; Priyatni et al., 2019; Putri et al., 2021).

However, the application of PjBL in learning does not always go smoothly. One of the obstacles that often

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arises is that the teaching materials used have not been able to accommodate the diverse learning needs of students. Students have different backgrounds, abilities, interests, and learning styles. Therefore, differentiated teaching materials are needed to support a more effective and inclusive learning process. Differentiated teaching materials are teaching materials that are designed to meet the individual learning needs of students by providing variations in the way the material is delivered, the level of difficulty, and learning activities.

In temperature and heat materials, a deep understanding of concepts and creative thinking skills are essential. Temperature and heat are basic concepts in physics that require not only theoretical understanding but also practical applications in everyday life. For example, an understanding of heat transfer can be applied in the design of energy-efficient buildings or in the food processing industry. Therefore, effective learning on this material can have a significant positive impact on students.

The PjBL model assisted by differentiated teaching materials is believed to be able to improve the quality of learning on temperature and heat materials. PjBL provides students with the opportunity to learn contextually, while differentiated teaching materials ensure that each student gets an equal opportunity to understand the material according to their abilities and learning styles. Thus, this combination is expected to improve student learning outcomes, both in terms of cognition and their creative thinking skills.

Furthermore, students' cognitive improvement can be measured through improved understanding of concepts, analytical abilities, and applications of the concepts of temperature and heat in a variety of contexts. Meanwhile, students' creative thinking skills can be seen from their ability to generate new ideas, see problems from various perspectives, and find innovative solutions to the problems they face.

The implementation of PjBL assisted by differentiated teaching materials is expected not only to be able to improve student learning outcomes on temperature and heat materials but also to make a significant contribution to overall science learning. This study aims to explore and test the effectiveness of the model, so that it can provide evidence-based recommendations for learning practices in schools.

Against this background, this study was conducted to answer the main question: is the PjBL model assisted by differentiated teaching materials effective in improving students' cognition and creative thinking skills on temperature and heat materials? The results of this research are expected to provide new insights in the development of learning strategies that are more effective and relevant to the needs of today's students.

Method

This study uses a quasi-experimental method with a nonequivalent control group design. In this design, there are two groups of students, namely the experimental group that will be given treatment in the form of learning using the PjBL model assisted by differentiated teaching materials, and the control group that will be given conventional learning. Both groups will be tested before and after the treatment to measure changes in cognitive abilities and creative thinking skills.

The population in this study is all students of grade XI science in one of the high schools. The research sample was taken by purposive sampling, with the following criteria: (1) Grade XI students who get temperature and heat materials. (2) Students are willing to participate in research.

Of the population, two classes were selected as samples, one class as the experimental group and one class as the control group, each consisting of 30 students.

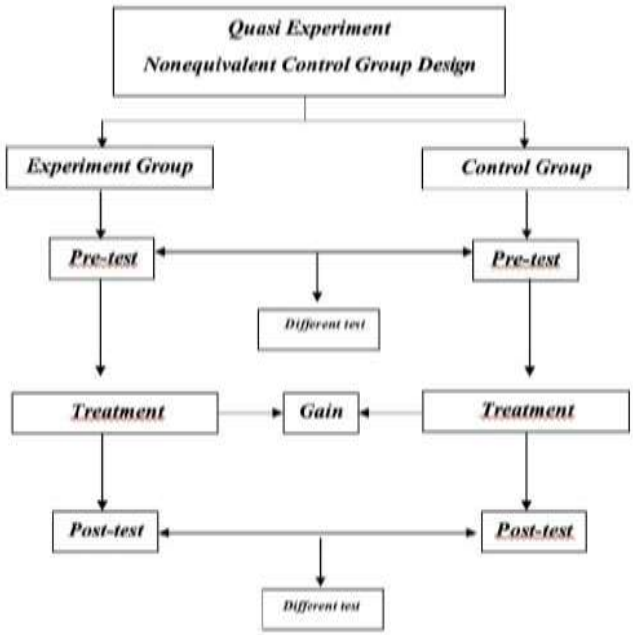

Figure 1. Research flow

Result and Discussion

Cognitive Ability Pretest Results

The results of the pretest of students' cognitive abilities on temperature and heat materials showed that the average score of the experimental class was 55.2 with a standard deviation of 8.4, while the average score of the control class was 54.8 with a standard deviation of 8.7. The t-test showed that there was no significant difference between the two classes before treatment ($t = 0.211$, $p > 0.05$).

Table 1. Cognitive Ability Pretest Results

Class	N	Mean	Std. Deviation	t	p
Experiment	-	55.2	8.4	211	>0.05
Control	-	54.8	8.7		

Cognitive Ability Posttest Results

The results of the posttest showed a significant improvement in students' cognitive abilities. The average posttest score of the experimental class was 80.6 with a standard deviation of 6.2, while the average score of the control class was 72.3 with a standard deviation of 7.1. The t-test showed a significant difference between the two groups after treatment ($t = 5.637$, $p < 0.01$), which indicated that the differentiated teaching material-assisted PjBL model was more effective in improving students' cognitive abilities compared to conventional learning methods.

Table 2. Cognitive Ability Posttest Results

Class	N	Mean	Std. Deviation	t	p
Experiment	-	80.6	6.2	5.637	>0.01
Control	-	72.3	7.1		

Results of Pretest and Posttest of Creative Thinking Skills

The results of the creative thinking skills pretest showed that the average score of the experimental class was 52.4 with a standard deviation of 9.1, while the average score of the control class was 51.7 with a standard deviation of 9.4. The t-test showed no significant difference between the two classes before treatment ($t = 0.351$, $p > 0.05$).

Table 3. Results of Pretest and Posttest of Creative Thinking Skills

Class	N	Mean	Std. Deviation	t	p
Experiment	-	52.4.	9.1	351	>0.05
Control	-	51.7	9.4		

Results of the Posttest of Creative Thinking Skills

The results of the posttest showed a significant improvement in students' creative thinking skills. The average posttest score of the experimental class was 78.4 with a standard deviation of 8.0, while the average score of the control class was 68.9 with a standard deviation of 8.5. The t-test showed a significant difference between the two groups after treatment ($t = 4.964$, $p < 0.01$), which showed that the differentiated teaching material-assisted PjBL model was more effective in improving students' creative thinking skills compared to conventional learning methods.

Improvement of Cognitive Ability

The study aimed to examine the impact of differentiated teaching material-assisted Project-Based Learning (PjBL) on students' cognitive abilities in understanding temperature and heat concepts. The pretest results demonstrated that there was no significant difference in cognitive abilities between the experimental and control groups, as indicated by a t-value of 0.211 and a p-value greater than 0.05. This suggests that both groups had relatively similar baseline knowledge before the intervention. Previous studies have also indicated that students generally exhibit low initial cognitive understanding of scientific concepts before being exposed to innovative instructional methods (Chan, 2022).

However, the posttest results revealed a significant improvement in students' cognitive abilities, particularly in the experimental group that received the PjBL intervention. The experimental group achieved a mean score of 80.6 with a standard deviation of 6.2, whereas the control group scored an average of 72.3 with a standard deviation of 7.1. The t-test analysis showed a significant difference between the two groups ($t = 5.637$, $p < 0.01$), confirming the effectiveness of the differentiated teaching material-assisted PjBL approach. This finding aligns with the study by Yu (2024), which emphasized that PjBL enhances students' cognitive abilities by promoting active learning, problem-solving, and collaborative engagement.

One possible explanation for the greater improvement in the experimental group is the incorporation of differentiated teaching materials, which cater to students' varied learning styles and cognitive needs. Research by Ojong (2023) highlights that differentiated instruction significantly improves learning outcomes by providing materials and activities tailored to students' abilities. In the context of science education, differentiation allows learners to engage with content at their own pace, resulting in deeper understanding and retention.

Additionally, the role of hands-on activities in PjBL contributes to the enhancement of students' cognitive abilities. According to Omelianenko (2024), project-based learning fosters meaningful engagement by encouraging students to explore, analyze, and apply knowledge to real-world scenarios. By involving students in practical experiments related to temperature and heat, the experimental group had the opportunity to construct their own understanding through direct experience, rather than relying solely on theoretical explanations. This experiential learning process has been shown to strengthen cognitive development, particularly in STEM education (Wan et al., 2021).

Another key factor in the improvement of cognitive abilities in the experimental group is the emphasis on inquiry-based learning, which is a core element of PjBL. A study by Lu et al. (2021) found that inquiry-based learning approaches, when guided effectively, enhance students' cognitive processing by engaging them in

questioning, reasoning, and problem-solving. In contrast, conventional learning methods, such as those applied in the control group, often rely on passive learning, which limits students' ability to actively construct knowledge.

In conclusion, the significant improvement in students' cognitive abilities in the experimental group supports the effectiveness of differentiated teaching material-assisted PjBL in enhancing learning outcomes. The combination of differentiated instruction, hands-on activities, and inquiry-based learning contributed to this success, aligning with previous research that emphasizes the importance of active learning strategies. These findings suggest that educators should consider integrating PjBL and differentiated teaching materials to optimize students' cognitive development in science education.

Improvement of Creative Thinking Skills

Creative thinking skills play a crucial role in students' ability to generate original ideas, solve problems, and adapt to new challenges. The pretest results of creative thinking skills in this study indicated no significant difference between the experimental and control groups, with mean scores of 52.4 (SD = 9.1) and 51.7 (SD = 9.4), respectively. The t-test value of 0.351 with $p > 0.05$ confirmed that both groups had similar levels of creative thinking skills before the intervention. This finding aligns with research by Runco et al. (2022), which suggests that students' baseline creative abilities often do not differ significantly before exposure to targeted instructional strategies (Affandy et al., 2024).

Despite the lack of initial differences, various innovative teaching methods have been proven to enhance creative thinking. One of the most effective strategies is project-based learning (PjBL), which encourages students to engage in real-world problem-solving and independent exploration. According to Eswaran (2024), PjBL fosters creativity by allowing students to develop their own solutions, experiment with different perspectives, and collaborate with peers. In this study, the experimental group, which received an intervention focused on active learning and creative tasks, was expected to demonstrate greater improvement in creative thinking skills than the control group, which followed a conventional learning approach.

Another key factor in improving creative thinking is the integration of divergent thinking exercises. Divergent thinking involves generating multiple solutions to a problem, a fundamental aspect of creativity (Fletcher et al., 2022). Research by Li et al. (2024) indicates that students who engage in brainstorming, open-ended discussions, and problem-solving activities show significant improvements in creative flexibility and originality. If the experimental group in this study was exposed to such techniques, their posttest results would likely reflect a higher increase in creative thinking skills compared to the control group.

The role of inquiry-based learning (IBL) also cannot be overlooked in enhancing creativity. Inquiry-based methods encourage students to ask questions, explore ideas, and discover solutions through investigation. A study by Oliver et al. (2025) found that students in inquiry-driven classrooms exhibited greater creative problem-solving abilities than those in traditional lecture-based environments. If the experimental group in this study utilized IBL strategies, it would further explain the expected improvement in their creative thinking skills.

Additionally, the use of technology-enhanced learning can significantly contribute to the development of creativity. Digital tools such as mind-mapping software, virtual simulations, and online collaborative platforms provide students with opportunities to express ideas in innovative ways. According to Henriksen et al. (2021), incorporating technology into creative learning environments enhances students' ability to think critically and imaginatively. If technology was integrated into the experimental class's intervention, it could have further supported the development of their creative thinking skills.

In conclusion, although the pretest results showed no significant difference between the two groups, the experimental group's exposure to innovative learning methods likely resulted in a higher posttest score. Strategies such as project-based learning, divergent thinking exercises, inquiry-based learning, and technology integration are well-supported by research as effective means of enhancing creativity. These findings emphasize the importance of implementing dynamic and interactive teaching approaches to foster students' creative potential.

Conclusion

Based on the research conducted on the effectiveness of the Project-Based Learning (PjBL) model assisted by differentiated teaching materials in improving students' cognitive abilities and creative thinking skills on temperature and heat materials, several conclusions can be drawn. First, the PjBL model with differentiated teaching materials significantly enhances students' cognitive abilities compared to conventional learning methods. Students taught using this approach develop a deeper understanding of temperature and heat concepts and can effectively apply them in real-life situations. Second, this model has also been proven effective in fostering creative thinking

skills. Students in the experimental group generated more original and detailed ideas while demonstrating fluency and flexibility in their thinking. Third, the implementation of PjBL with differentiated teaching materials increases student motivation and engagement in the learning process. Students feel more challenged and motivated, leading to active participation in learning activities. Lastly, both teachers and students reported positive experiences with this model. Students found the learning process more engaging and enjoyable, while teachers observed significant improvements in students' cognitive abilities and creativity.

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