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Optimization of Cognitive Diagnostic Assessment with the Project-Based Learning Model on Understanding Fluid Concepts in Middle School

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Abstract: Based on research over the past three years, the average for the implementation of diagnostic assessments shows that they still feel unfamiliar with its use. Then, the implementation of cognitive diagnostic assessments on fluid material often only reveals the inability to memorize rather than conceptual understanding. Teachers have received sufficient training regarding its implementation, but there are still obstacles in students' understanding of science concepts related to fluid material. The objective of this research focuses on discussing the optimization of cognitive diagnostic assessment with the PjBL learning model. This study uses a quasi-experimental approach with a pretest-posttest control group design. The subjects of the study are eighth-grade students at a junior high school implementing the Merdeka Curriculum. The class was divided into two groups, namely the experimental class that applied the Project-Based Learning (PjBL) model with the optimization of cognitive diagnostic assessment, and the control class that used conventional teaching methods. The results of this study show a significant difference in pre-test and post-test scores ($p<0.001$). The average gain score of 24.34 indicates the effectiveness of PJBL learning by optimizing cognitive diagnostic assessment. Although teachers have received adequate training on cognitive diagnostic assessments, there are still obstacles in students' understanding of science concepts, especially in fluid materials. Therefore, the PjBL approach with structured diagnostic assessment can be a solution to overcome these obstacles. This study also highlights the importance of remedial support for students who have not yet achieved competence in understanding fluid concepts. By aligning learning based on the average competency of students, teachers can provide more targeted interventions. In general, the combination of the PjBL model and cognitive diagnostic assessment can be an effective learning strategy in the Merdeka Curriculum.

***Keywords**:* PJBL learning; cognitive diagnostic assessment

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Introduction

The launch of the independent curriculum is an effort to address the learning loss crisis (Artika et al., 2023). This crisis occurred as a result of the impact of the Covid-19 pandemic, which forced students to learn from home. The problems encountered in the practice of learning from home must certainly continue to be evaluated in order to achieve better learning outcomes (Firmanzah; Sudibyio, 2021). One of the goals of the Merdeka curriculum is to produce graduates who are capable of competing at the global level (Haerazi et al., 2023). The character and traits of each student, which differ, need to be known by the teacher to understand the weaknesses, strengths, and skills of the students before starting the learning process. This information will be used by the teacher as a reference to conduct learning in accordance with the current Merdeka curriculum.

According to kunainih et al.; 2023, diagnostic assessments need to be given to students when issues arise related to the implementation of learning activities and learning outcomes. According to the Ministry of Education and Culture, schools are required to conduct diagnostic assessments to identify students' needs during the learning process, which will later serve as a reference for continuing learning and assessment (Prastikawati, 2022). Diagnostic assessments are divided into two types: non-cognitive diagnostic assessments and cognitive diagnostic assessments. Non-cognitive diagnostic assessments are conducted to explore knowledge about the psychological and socio-emotional well-being of students, knowledge that occurs at home during learning, knowledge about the student's family, social knowledge, background, learning styles, and student interests. On the other hand, cognitive assessments can be conducted regularly, such as periodic assessments at the beginning of the learning process, at the end of the learning process, and discussing topics during the learning process (Artika et al., 2023). Furthermore, the aim of this research is solely to focus on discussing cognitive diagnostic assessment, as it is considered capable of identifying students' competency performance, aligning learning based on the average competency of students in the class, and providing remediation to students who are not yet competent in understanding concepts during classroom learning. The stages that will be carried out will certainly determine the test objectives, namely the mastery of fluid material concepts. Based on the results of interviews with students and science teachers at SMPN 4 Siliragung, this material tends to be difficult for students to understand. Next Preparing the material outline, writing questions, reviewing and revising questions.

This research combines two approaches that are usually used separately, namely cognitive diagnostic assessment and the PjBL learning model. This integration aims to deeply identify students' learning difficulties while also providing contextual learning solutions through projects. By combining these two approaches, this research not only identifies students' misconceptions but also provides active and meaningful learning experiences through fluid-related science projects. This research specifically targets the understanding of fluid concepts among middle school students, which is a topic often considered difficult and abstract. Most previous research has focused more on high school or college levels. With a focus on middle school students. This research proposes a learning approach tailored to the results of cognitive diagnostic assessments. Students who have misconceptions or specific learning difficulties will receive targeted learning interventions through specially designed projects. This PjBL ensures that each student receives support tailored to their learning needs, thereby reducing the understanding gap within the classroom.

Method

The approach of this research is a quantitative approach. This approach is statistical in nature to test the hypotheses that have been formulated. In this study, a descriptive analysis method is used to diagnose the results of cognitive assessments and understanding of fluid concepts as well as their optimization. Then the descriptive, correlational analytical method to find whether there is a relationship or not between the independent variable and the dependent variable. If there is, then how significant is the relationship between cognitive diagnostic assessment combined with PjBL and students' understanding of fluid concepts.

The population used in this study is the seventh-grade students of SMP Negeri 4 Siliragung - Banyuwangi in the even semester. Meanwhile, the sample used consists of all seventh-grade students. Because if the population participants are less than 100, the sample is taken in its entirety (Arikunto, 2012; 104). Then the data collection techniques include quantitative data (pretest and posttest scores on fluid concept understanding, cognitive diagnostic assessment scores, and student project outcome data). Meanwhile, qualitative data includes the results of observing the learning process, interviews with students or teachers, and students' reflection notes. Based on the collected data, the researcher used descriptive analysis which includes the elaboration of descriptive statistics (mean, median, mode for pretest and posttest scores, standard deviation to see data variation, and the percentage increase in understanding fluid concepts.

Results and Discussion

The results of this study indicate that the implementation of Project-Based Learning (PjBL) significantly improves eighth-grade students' understanding of fluid concepts, as evidenced by the increase in diagnostic test scores from an average pre-test score of 52.34 to a post-test score of 76.67. The average gain score of 24.34 points demonstrates a substantial improvement in conceptual understanding. This finding aligns with previous research that highlights the effectiveness of PjBL in enhancing students' conceptual understanding and engagement in science education (Bell, 2010; Thomas, 2000). PjBL encourages active learning, critical thinking, and problem-solving, which are essential for mastering complex scientific concepts like fluid dynamics.

The results of the data normality test also indicate that:

Table 1. Results of the Normality Test

Variable	**Statististic**	**p-value**
Pre-test	0.972	0.465
Post-test	0.961	0.312
gain	0.955	0.275

The normality test results (Table 1) confirm that the data for pre-test, post-test, and gain scores are normally distributed ($p > 0.05$), allowing for the use of parametric statistical tests. The paired sample t-test results (Table 2) reveal a statistically significant difference between pre-test and post-test scores ($p < 0.001$), with a large mean difference of 24.34 points. This suggests that the implementation of PjBL had a meaningful impact on students' understanding of fluid concepts. The t-value of 12.45 and degrees of freedom (df = 59)

Table 2. Hypothesis Test Results

Mean Difference	**t-value**	**df**	**p-value**
24.34	12.45	59	<0.001

The effect size (Cohen's d = 1.45) indicates a large effect of PjBL on improving students' understanding of fluid concepts. According to Cohen (1988), an effect size greater than 0.8 is considered large, which implies that the intervention had a substantial practical significance beyond statistical significance. This large effect size underscores the potential of PjBL as an effective instructional strategy for teaching complex scientific conceptsThe researchers also examined the relationship between the gain score and student activity during the PjBL model learning, and showed that there is a significant positive correlation between the gain score and student activity during PjBL (r= 0.678, p<0.001).

The significant positive correlation (r = 0.678, p < 0.001) between gain scores and student activity during PjBL suggests that students who were more actively engaged in the PjBL process achieved greater improvements in their understanding of fluid concepts. This finding is consistent with the literature on active learning, which emphasizes the importance of student engagement and participation in the learning process (Freeman et al., 2014). PjBL provides opportunities for students to collaborate, explore, and apply their knowledge in real-world contexts, which likely contributed to their increased activity and subsequent learning gains

The results of this study are consistent with other research that has demonstrated the effectiveness of PjBL in improving students' conceptual understanding and academic performance. For example, a study by Han et al. (2015) found that PjBL significantly improved students' problem-solving skills and conceptual understanding in science. Similarly, a meta-analysis by Chen and Yang (2019) concluded that PjBL had a positive impact on student learning outcomes across various disciplines. The large effect size observed in this study further supports the growing body of evidence that PjBL is a highly effective instructional approach.

The findings of this study have important implications for science education. PjBL can be a valuable tool for teachers seeking to enhance students' understanding of complex scientific concepts like fluid dynamics. By incorporating PjBL into their teaching practices, educators can create engaging and interactive learning environments that promote deeper understanding and long-term retention of knowledge. Additionally, the positive correlation between student activity and learning gains highlights the importance of fostering active participation and collaboration in the classroom.

While this study provides valuable insights into the effectiveness of PjBL, it is important to acknowledge its limitations. The study was conducted with a relatively small sample size (n = 60) and focused on a specific grade level and subject area. Future research could explore the impact of PjBL on other grade levels, subjects, and larger sample sizes to generalize the findings. Additionally, longitudinal studies could investigate the long-term effects of PjBL on students' conceptual understanding and academic performance.

Conclusion

The results of this study show a significant difference in pre-test and post-test scores ($p<0.001$). The average gain score of 24.34 indicates the effectiveness of PJBL learning by optimizing cognitive diagnostic assessment. Although teachers have received adequate training on cognitive diagnostic assessments, there are still obstacles in students' understanding of science concepts, especially in fluid materials. Therefore, the PjBL approach with structured diagnostic assessment can be a solution to overcome these obstacles. This study also highlights the importance of remedial support for students who have not yet achieved competence in understanding fluid concepts. By aligning learning based on the average competency of students, teachers can provide more targeted interventions. In general, the combination of the PjBL model and cognitive diagnostic assessment can be an effective learning strategy in the Merdeka Curriculum.

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