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The Influence of Project-Based Learning Method in Online Learning on the Cognitive Abilities

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ABSTRACT

Effective education is one that explores and maximizes students' potential by creating learning experiences that fully engage them. This research aims to investigate the impact of the Project-Based Learning (PBL) method on the cognitive abilities of 5th-grade students during online learning. This study adopts a quasi-experimental design with the non-equivalent control group approach, utilizing purposive sampling. The sample comprises 20 students in the experimental group and 21 students in the control group. Research instruments include observation guidelines, cognitive ability tests, and documentation checklists. Data analysis involves tests for normality, homogeneity, and hypothesis testing using independent sample t-tests and paired sample t-tests. Results indicate a significant improvement in cognitive abilities in the experimental group, as evidenced by the paired sample t-test with a calculated t-value of 11.048 higher than the critical t-value of 2.086. This suggests that the Project-Based Learning method has a positive influence on the cognitive abilities of 5th-grade students. The findings support the conclusion that the implementation of Project-Based Learning in online education has a notable impact on the cognitive skills.

Keywords
Cognitive Abilities
Elementary School
Online Learning
Project-Based Learning

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Introduction

The COVID-19 pandemic is a devastating calamity affecting the world's entire population. It has swept across the globe, including Indonesia. Every sector of community life has been disrupted, particularly education. Starting from mid-March 2020, the President of Indonesia instructed the entire population to learn, work, and worship from home. According to Circular No. 4 of 2020 from the Ministry of Education and Culture, all institutional activities must maintain social distancing, and all educational content should be delivered to individuals' homes [1]. The educational process in schools serves as a public policy tool for enhancing knowledge and skills [2]. Based on interviews conducted at SD Negeri 2 Tulus Ayu (a primary school in Sumatera Selatan), students express that school is an enjoyable activity and place where they can play and interact with each other. Schools play a crucial role in improving students' social skills and awareness. However, the current situation has abruptly halted school activities due to the disruptions caused by the COVID-19 pandemic.

The implications of the circular led to schools adopting remote student learning. To achieve meaningful learning, teachers must select appropriate models for effective learning. Primary schools have also implemented online or remote learning guided by parents. According to Ref. [3], online learning utilizes the internet in the learning process, giving students the flexibility to study anytime and anywhere. Students can interact with teachers using applications such as Classroom, video conferences, telephone or live chat, Zoom, and WhatsApp groups. This form of learning is an educational innovation addressing the challenges of diverse learning resources. A learning model's success depends on the students' characteristics to achieve academic goals.

Effective education maximizes and develops students' potential. This is achieved by creating learning experiences that fully engage students. According to Ref. [4], education is students' awareness of the world's reality, not merely accumulating and memorizing knowledge. Learning is the process undertaken by teachers to make students learn. Ref. [5] states that learning is a deliberate effort by educators to convey knowledge and organize and create an environmental system with various methods, allowing students to learn effectively and efficiently with optimal results. Teachers are facilitators and guides, implementing multiple approaches, strategies, techniques, and creative use of teaching aids or media to achieve learning goals. Success in meaningful learning depends on teachers' ability to apply effective teaching methods [6].

Teachers have a significant role in the learning process. Educators need to apply creative models or strategies to support learning outcomes. According to Ref. [7], a learning model is a systematic procedure or pattern used as a guide to achieve learning, encompassing strategies, techniques, methods, materials, media, and assessment tools. The proper use of

learning methods helps students develop more effective and innovative learning, and teachers must create engaging learning experiences to make learning more accessible for students, aiding them in overcoming learning difficulties and improving learning outcomes.

During the COVID-19 pandemic, distance learning was implemented using various online platforms to avoid physical contact and reduce the spread of the virus. In his May 2, 2020 speech, the Minister of Education emphasized the need for effective learning through collaboration between teachers and students. Project-based learning (PBL) is an option to make learning enjoyable and motivate students to participate actively.

PBL is an instructional approach built on real-world learning activities and tasks that challenge students in group settings [8]. According to Ref. [9], it centers on students and provides meaningful learning experiences. Ref. [10] defines one as a learner-centered model involving in-depth investigations into challenging, real-world problems and questions. Ref. [11] states that this approach allows educators to manage classroom learning by applying project work, encouraging complex tasks based on challenging questions, and leading students to design, solve problems, make decisions, conduct investigations, and work independently.

Distance learning involves using the internet and can take place anywhere and anytime without fixed schedules and face-to-face interaction, utilizing various applications. WhatsApp is one such application used in distance learning due to its practicality, effectiveness (low data usage), and accessibility. However, challenges such as limited access to smartphones or the internet can hinder the learning process. Students may also face boredom and complete tasks hastily or not at all. Students' concentration at home differs from that at school, as distractions like watching YouTube or playing online games can divert attention from online learning via WhatsApp.

The ineffectiveness of distance learning significantly impacts the decline in students' cognitive abilities. If cognitive abilities are low, the educational goals may not be achieved optimally. During the COVID-19 pandemic, teachers are challenged to enhance students' cognitive abilities. However, not all teachers can create diverse teaching methods. According to Ref. [12], cognitive abilities develop gradually in conjunction with physical and nerve development in the central nervous system. One influential theory explaining cognitive development is Piaget's theory. Ref. [13] defines cognitive processes as thinking abilities that allow individuals to connect, assess, and consider events or incidents. Cognitive abilities are the foundation for a child's ability to think, related to intelligence that marks a person with various interests primarily directed toward learning ideas.

Ideal student-centered learning places students at the center of the learning process [14]. Students are expected to build concepts and develop cognitive abilities. Students must

have cognitive skills to solve problems in learning. Students should be directed to higher levels through innovative and varied learning activities. Teachers often lecture in the current learning process, causing students to find the learning experience dull or monotonous. The lack of creativity in using varied methods makes students passive. Learning methods should be prepared in diverse ways to have a maximum impact on students' learning styles. Teachers must develop knowledge and mastery of concepts, attitudes, morals, and critical thinking skills for students. One of these thinking skills is cognitive ability, which should be trained and developed to support learning goals.

Based on observations at the school, it is evident that students' science learning outcomes are still low. The initial condition of science learning outcomes in the knowledge aspect did not meet the Minimum Completion Criteria. The average learning outcome was 57%, with a completion rate of 57.89%. This is due to inappropriate teaching methods, lack of interaction between teachers and students, and inadequate time for students to interact with learning media/tools.

The choice of a learning model should align with the learning goals. PBL will be applied as a research method. The impact of one is expected to actively involve students, enrich their experiences, and enhance their creativity. Students should be able to solve problems systematically and logically, creating a student-centered learning environment that ultimately improves their cognitive abilities. Based on the issue, this research aims to determine the influence of project-based learning methods in online learning on the cognitive skills of fifth-grade students.

Literature Review

A. Project-Based Learning in Education

PBL is an instructional approach that engages students in solving real-world problems or addressing community issues by creating meaningful projects [15]. It allows students to develop their creativity, problem-solving, and critical-thinking abilities while actively participating in learning [16]. The project-based learning method exhibits several critical characteristics, according to various experts. It involves direct student engagement, connects learning to the real world, incorporates research, encompasses multiple knowledge and skills, unifies these skills, unfolds over time, and culminates in creating a specific product. Effective PBL, as highlighted by other scholars, directs students to invest in essential ideas, involves an inquiry process, relates to student needs and interests, centers on students through independent product creation and presentation, and addresses real-world, authentic problems and issues [17].

The implementation of this approach follows a systematic approach [18]. The six steps outlined by Delise guide educators and students through the process:

1. Connecting with the problem: Educators select and present difficulties linked to students' daily lives, creating relevance.
2. Setting up the structure: After problem engagement, educators establish a framework for students to work through challenges systematically.
3. Visiting the problem: Focused on students' ideas, educators guide them in generating facts and refining their understanding of the problem.
4. Revisiting the problem: Small groups reconvene, reporting observations and allowing educators to assess sources, time usage, and action plan effectiveness.
5. Producing a product/performance: Students create a problem-solving outcome, evaluated by educators for content quality and skill mastery.
6. Evaluating performance and the problem: Students assess their work performance and propose solutions to enhance reflective learning.

Research suggests that PBL positively influences student engagement, satisfaction, and motivation [19][20]. The method results in better literacy outcomes when executed effectively than traditional approaches. Students benefit from active involvement, inquiry-based learning, and the application of creative and critical thinking skills. It aligns with the principles of student-centered education, emphasizing the importance of connecting learning to real-world issues. Project-based learning emerges as a dynamic and practical approach in education, fostering student development in various domains. Its emphasis on real-world problem-solving, creativity, and active student engagement aligns with the evolving needs of education. The outlined characteristics and steps provide educators with a structured framework to implement it successfully, ultimately contributing to enhanced cognitive abilities and a more meaningful learning experience for students.

B. Cognitive Ability

"Cognitive" is derived from cognition, meaning understanding or comprehension. Cognition encompasses acquiring, organizing, and applying knowledge [21]. Broadly, cognitive abilities involve all mental behaviors related to learning, attention, reasoning, problem-solving, information processing, imagination, estimation, thinking, and belief. Scholars in cognitive psychology assert that an individual's behavior is continually based on cognition, the act of recognizing or thinking about the situation in which the behavior occurs [22].

According to Ref. [23], cognitive ability is the capacity that enhances students' thinking skills. It is vital to apply all cognitive domains in each learning session for quality education [24]. Cognitive abilities involve mastery in the intellectual domain, encompassing knowledge and thinking skills, such as lower-order thinking skills (LOTS) like remembering,

understanding, and applying, and higher-order thinking skills (HOTS), including analyzing, evaluating, and creating.

In the context of primary school children, cognitive development extends beyond rote memorization and academic achievements. It includes critical thinking, control, information processing, analysis, problem-solving, and understanding cause and effect [25]. By the end of fifth grade, students typically demonstrate cognitive development by understanding perspectives, explaining concepts or problems from various angles, predicting consequences and planning, actively seeking information, and grasping abstract connections, such as the impact of climate crises on their environment.

Cognitive development in eleven to twelve-year-olds signifies a shift towards more abstract thinking, logical reasoning, and the ability to anticipate hypothetical scenarios. This phase, known as the formal operational stage, allows children to think flexibly and effectively when confronting complex problems. The transition from concrete functional thinking, focused on tangible objects, to legal, operational thinking, marked by abstract reasoning and hypothesis-deductive thinking, represents the culmination of cognitive development.

In the educational context, the formal operational stage aligns with the fifth and sixth grades, where cognitive abilities advance to evaluating and creating. This research specifically focuses on analyzing, evaluating, and creating cognitive skills for students aged 11 years (fifth grade). Understanding these cognitive milestones is crucial for designing practical learning activities that cater to students' intellectual growth and critical thinking skills in this developmental stage.

Material and Methods

A. Research Context

The research method used in this study involves a quasi-experimental design, specifically a non-equivalent control group design. This design investigates the influence of a specific treatment on a controlled condition. This design involves two groups: experiment and control groups. Before applying the treatment, both groups undergo a pretest to measure their initial conditions. The experiment group receives a specific treatment, which is the implementation of project-based learning, while the control group does not receive any special treatment. Subsequently, both groups undergo a posttest to assess the outcomes.

The research is conducted at SD Negeri 2 Tulus Ayu, District of Belitang Madang Raya, OKU Timur Regency, Sumatera Selatan. The study takes place in March 2022, involving the entire fifth-grade student population of the school for the academic year 2021/2022, totaling 42 students. The sample consists of two groups: 21 students in the experiment group and 21 students in the control group. The research variables include the independent variable

(teaching method) and the dependent variable (cognitive ability of fifth-grade students). The teaching methods are project-based learning for the experiment group and discussion methods for the control group.

B. Instruments and Data Analysis

Data collection techniques involve observation and cognitive assessment. Observations include structured observations of implementing project-based learning and regular discussion-based teaching. Cognitive assessment includes pretests and posttests focusing on the student's cognitive abilities. Instruments used for data collection include observation guidelines and cognitive assessment tests. These instruments are validated through expert judgment and content validity. The reliability of the cognitive ability test is measured using the Cronbach's Alpha coefficient.

Data analysis includes testing the normality and homogeneity of the data. The normality test uses the Kolmogorov-Smirnov test, and the homogeneity test involves the Fisher test. Once these prerequisites are met, hypothesis testing is conducted using independent sample t-tests and paired sample t-tests. The results of this research provided insights into the impact of project-based learning on the cognitive abilities of fifth-grade students, comparing it with the traditional discussion-based teaching method.

Results

A. Pretest and Posttest Results of Cognitive Ability

The experiment group implemented Project-Based Learning on March 11, 2022. The pretest involved 21 students, and the data was processed using SPSS 24. The statistical results of the pretest for cognitive ability in the experiment group are as follows:

Table 1. Pretest and Posttest Results of Cognitive Ability

	Experiment Group		Control Group	
	Pretest	Posttest	Pretest	Posttest
Mean	67.33	87.67	61.57	73.19
Median	68.00	88.00	62.00	75.00
Mode	70.00	85.00	55.00	65.00
Standard Deviation	6.14	4.76	6.04	5.75
Minimum	56.00	80.00	50.00	65.00
Maximum	76.00	95.00	71.00	82.00

B. Data Analysis Results

Data analysis was conducted to address the hypotheses established in the previous chapter. The analyses included normality and homogeneity tests and hypothesis testing using

independent sample t-tests and paired sample t-tests. The results of normality and homogeneity tests are presented in Table 2 and Table 3.

1. Normality Test

Normality tests were conducted on pretest and posttest scores for cognitive ability in the experiment and control groups. The normality of the data distribution is confirmed if the Asymp. Sig (2-tailed) is greater than the alpha level (0.05). The summary of normality test results for pretest and posttest data in the experiment and control groups, calculated using SPSS version 24, is presented in the table below:

Table 2. Normality Test (Cognitive Ability)

Group	Data	Asymp. Sig (2-tailed)	Interpretation
Experiment	Pretest	0.200	Normal
	Posttest	0.200	Normal
Control	Pretest	0.200	Normal
	Posttest	0.200	Normal

The results indicate that both pretest and posttest data for the experiment and control groups have Asymp. Sig (2-tailed) values greater than 0.05 suggest normal distribution.

2. Homogeneity Test

Once normality is established, a homogeneity test is conducted. Using SPSS 24, the calculations indicate homogeneity if the calculated significance value exceeds the set significance level of 5% (0.05). The results are summarized in the table below:

Table 3. Homogeneity Test Results

Data	Levene Statistic	df1	df2	Sig (2-tailed)	Interpretation
Pretest: Experiment and Control Groups	0.071	1	40	0.792	Homogeneous
Posttest: Experiment and Control Groups	0.945	1	40	0.337	Homogeneous

The homogeneity test results show that both pretest and posttest data for the experiment and control groups are homogeneous, as the calculated significance values are more significant than 0.05. The detailed calculations can be found in the appendix.

C. Hypothesis Testing

1. Independent Sample t-test:

The independent sample t-test was conducted on pretest scores for cognitive ability between Project-Based Learning and discussion methods. The obtained t-value (3.068) is smaller than the critical t-value (2.021), with 40 degrees of freedom at a 5% significance level. This indicates a significant difference in cognitive ability between Project-Based

Learning and discussion methods. Like the pretest, the independent sample t-test was applied to posttest scores. After confirming normality and homogeneity, the t-test yielded a t-value (2.473) more significant than the critical t-value (2.021) with 40 degrees of freedom. This indicates a significant difference in posttest cognitive ability between Project-Based Learning and discussion methods.

Table 4. T-Test Results

Source	t-value	t-table	df	p-value	Conclusion
Pretest: Project-Based Learning vs. Discussion	3.068	2.021	40	0.004	Significant
Posttest: Project-Based Learning vs. Discussion	2.473	2.021	40	0.018	Significant

2. Paired Sample t-test

The paired sample t-test was conducted on pretest and posttest scores within the experiment group. The t-value (11.048) is greater than the critical t-value (2.086) with 20 degrees of freedom, indicating a significant difference in cognitive ability between pretest and posttest scores in the experiment group. Similarly, the paired sample t-test was applied to the pretest and post-test scores within the control group. The t-value (10.453) is greater than the critical t-value (2.086) with 20 degrees of freedom, indicating a significant difference in cognitive ability between pretest and posttest scores in the control group.

Table 5. Paired Sample T-test Results

Source	t-value	t-table	df	p-value	Conclusion
Pretest and Posttest: Experiment group	11.048	2.086	20	0.000	Significant
Pretest and Posttest: Control group	10.453	2.086	20	0.000	Significant

Discussion

The subject of science encompasses a student's exploration of knowledge, including facts, processes, products, and theories related to natural phenomena. Science is a discipline that delves into understanding the universe, combining observations of various natural and artificial environmental elements. Mastering science requires not only memorization but also the application of reasoning skills. Cognitive ability, defined as a student's awareness and knowledge of thinking processes, plays a crucial role in problem-solving.

Cognitive ability involves high-level thinking activities that control ongoing thought processes. PBL is identified as an effective method for fostering cognitive skills among students. According to Ref. [16], it is an approach that supports students' cognitive skills, encouraging critical and creative thinking. Implementing PBL involves engaging students in open-ended problem-solving and applying their knowledge to produce authentic projects [11]. Our study employed it as an instructional method to enhance cognitive abilities in a fifth-grade science

class. The pretest results indicated a significant difference in cognitive skills between the experiment and control groups. The subsequent sections discuss the conditions before and after the intervention, shedding light on the impact of one on cognitive development.

The pretest results revealed a substantial difference in cognitive abilities between the experiment and control groups. This initial disparity emphasized the need for differentiated instructional strategies to address the varying mental levels within the classroom. Following this recognition, the experiment group underwent PBL, while the control group received traditional discussion-based instruction. The process unfolded through several stages, aligning with Stripling's characteristics of effective one, involving students in essential investigations, creative and critical thinking, and constructing their learning. This approach engaged students in planning, implementing, and presenting projects related to the science concepts covered [9],[20]. The six steps of PBL were followed: designing the problem, planning the project, scheduling, monitoring activities, testing results, and evaluation. The PBL process prompted students to delve into the material collaboratively, fostering autonomy and real-world applications. The students were guided through questioning, discussions, and hands-on projects, resulting in a deeper understanding of the topics. The assessment was based on the projects' outcomes, encouraging metacognitive skills among students.

However, challenges emerged during the PBL implementation, including the relatively lengthy time required for project completion and students' unfamiliarity with self-directed learning. Despite these challenges, the engagement and enthusiasm observed among the students indicated its effectiveness in creating meaningful learning experiences. In contrast, the control group, undergoing traditional discussion-based instruction, exhibited less enthusiasm and a more passive demeanor. The teacher dominated the learning process, delivering content through direct instruction, discussions, and assignments. The limitations of this method became apparent as students struggled to engage with the material actively. The lack of active involvement hindered the development of new ideas, contributing to limited cognitive growth.

Comparing the outcomes of the two instructional methods, it was evident that PBL significantly contributed to students' cognitive development. The experiment group demonstrated increased enthusiasm, active participation, and improved cognitive abilities. The authentic projects created through this approach showcased their understanding of scientific concepts and fostered creativity and critical thinking. On the other hand, the control group, receiving traditional instruction, exhibited limited cognitive growth [16],[22]. The lack of active participation hindered the development of new ideas and deeper understanding. Its

effectiveness in enhancing cognitive abilities aligns with previous research by Ref. [8],[15], and [16], emphasizing its superiority over conventional teaching methods.

The finding provides valuable insights into the impact of PBL on cognitive abilities in science education. PBL emerged as a potent instructional method, fostering active engagement, creativity, and critical thinking among students. The challenges encountered during implementation, such as time constraints and initial resistance, were outweighed by the positive outcomes observed. The study underscores the importance of incorporating instructional methods beyond traditional discussions to enhance cognitive abilities. Science education should not solely focus on content delivery but also emphasize problem-solving, creativity, and critical thinking skills [19],[26]-[28]. PBL is a promising approach to achieving these goals, providing a framework for students to construct their learning actively. This study contributes to the growing body of research supporting this approach as a powerful tool for cognitive development. Educators are encouraged to explore and implement innovative instructional methods like PBL to create meaningful and impactful learning experiences for their students, preparing them for the complex challenges of the future.

Conclusion

Project-based learning (PBL) in science education significantly enhanced fifth-grade students' cognitive abilities by emphasizing active engagement, creativity, and critical thinking. A pretest revealed a notable difference between the PBL-exposed experiment and traditional instruction control groups. Implementing this approach led to a dynamic and collaborative learning experience, with students demonstrating enthusiasm and autonomy in solving real-world science problems. Despite challenges like time constraints and initial teacher guidance reliance, the positive outcomes, including improved content mastery and critical thinking, surpassed the drawbacks. In contrast, the control group showed limited cognitive growth in a passive learning environment. The study underscores this approach's transformative potential in meeting modern education demands and preparing students for the complexities of the 21st century. Educators are urged to adopt innovative approaches like PBL to nurture holistic student development for future challenges.

Conflict of Interest

The authors declare that there is no conflict of interest.

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