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Project-Based Learning in Fostering Creative Thinking and Mathematical Problem-Solving Skills: Evidence from Primary Education in Indonesia

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Abstract. The interdependence between the Project-Based Learning (PjBL) Model and the growth and enhancement of Creative Thinking and Mathematical Problem Solving Skills in Elementary Schools is unquestionable nowadays. Prior studies have yet to discover concrete evidence regarding the interdependence being discussed. This study highlighted cognitive abilities related to creative thinking and mathematics problem-solving by implementing the Project-Based Learning Model. This research was a quasi-experiment with a pretest-posttest control group design involving 43 students in the sixth grade of two elementary schools; data was collected through test and classroom observation, and then the data was analyzed using Multivariate Analysis of Variance (MANOVA). Conversely, students exposed to project-based learning models exhibit higher skill levels in creative thinking and problem-solving than those instructed using conventional learning models. The project-based learning model significantly impacted elementary school children's creative thinking and mathematics problem-solving skills. These findings suggest that the Project-Based Learning Model is acceptable for instructors seeking to foster creativity in teaching mathematics at the primary school level in Indonesia or other countries with comparable settings.

Keywords: higher-order thinking skills; mathematics; primary education; project-based learning

1. Introduction

Education stakeholders are suggested to address these advancements and challenges; it is necessary to cultivate a generation capable of addressing these issues through transforming methods of instruction that highlight meaningful learning and offering students training in higher thinking abilities. It is not feasible to adequately prepare students for today and the future by simply

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providing them with ineffective teaching methods that rely exclusively on the teacher's knowledge and educational activities (Arici, 2023; Safie & Zakaria, 2023).

Educators are strongly encouraged to pursue a learning process of excellent standards; employing a unique and innovative strategy is necessary by selecting learning models and methodologies that can effectively guide students in problem-solving tasks that need higher-order thinking skills (HOTs). In order to facilitate the development of students' HOTs, students must become familiarized with activities that specifically target the enhancement of these skills (Astutik et al., 2020; Tanujaya et al., 2021). In this instance, learners can recall and comprehend a concept, examine and combine information, and assess and generate ideas effectively. Moreover, the notion that has been comprehended can persist in their memory for an extended period (Kurniawan et al., 2024; Tanjung et al., 2020).

Elementary school-aged students engage in concrete operational learning, which involves actively interacting with physical objects or real-life experiences as part of their learning process (Leasa, 2020; Liu, 2023). In this case, students see examples of geometric models, covering both two-dimensional figures and spatial geometry, that align with what they experience in the educational setting, both within the school premises and within their homes. In order to enhance students' comprehension of math, it is of the utmost importance to prioritize contextual learning in elementary schools, particularly in mathematics. Contextual learning allows students to improve their skills and comprehend mathematical concepts through hands-on learning experiences. Teachers must utilize resources that facilitate students' comprehension of learning content. Therefore, teachers should employ engaging learning models, media, and specific teaching aids to assist students in comprehending mathematical concepts (Handayani & Iswantiningtyas, 2020; Marbán et al., 2021; Shidqi et al., 2023).

In this scenario, facilitated learning must be centered on HOTs, which will ultimately develop creative thinking skills and the capacity to solve problems (Khalid et al., 2020; Saldo & Walag, 2020). Every learner is required to possess the thinking skill known as HOTs in order to solve mathematical issues. It has been stated by Thompson, as cited in (Astuti et al., 2019), that several actions can be performed using HOTs, which include (1) making determinations, (2) taking action to address challenges, (3) incorporating new objects, (4) making predictions, and (5) solving non-routine circumstances. When engaging in HOTs, students must employ comprehensive, non-algorithmic reasoning to solve problems, utilizing various problem-solving processes. HOTs are derived from Bloom's Taxonomy, specifically the cognitive domain encompassing higher levels of thinking, such as analyzing, evaluating, and producing (Kurniawan et al., 2024; Widiatsih et al., 2020).

Field experiences obtained through collaborative tasks with partner teachers throughout a field practice internship provide numerous challenges in the classroom teaching of mathematics. These challenges encompass insufficient teacher preparation and limited chances for students to participate in problem-solving activities. As a result, students tend to focus on solving routine problems rather than developing their problem-solving skills, and more emphasis should be placed on non-routine problem-solving abilities (Nuryadin et al., 2023; Tamur et al., 2020). This idea aligns with Arends' viewpoint (Arends, 2013), who said that teachers often emphasize the expectation for students to acquire knowledge rather than teaching them how to learn. Similarly, instructors frequently require students to solve issues without adequately instructing them on methods for problem-solving (Cook, 2020; Li, 2022). In addition, studying mathematics in the classroom is frequently discussed in teacher preparation as a factor contributing to learners' inability to reach their full learning potential. The development of problem-solving skills is not supported by educational instruction approaches that solely cater to the development of mathematical skills (Schindler & Bakker, 2020; Son et al., 2020).

In context of a research project on the problem-solving skills of students learning mathematics at Primary Schools in Indonesia was carried out by (Kurniawan et al., 2024; Rusilowati et al., 2023; Tanjung et al., 2020; Widiatsih et al., 2020) through the publication of their research in acknowledged international journals. However, their study did not focus on the examination of empirical evidence regarding the effectiveness of the PjBL model in developing and enhancing creative thinking skills, HOTs, and problem-solving skills in elementary school mathematics instruction. The findings of this research demonstrated the strong connection between the implementation of PjBL and the development of creative thinking skills, HOTs, and problem-solving skills in elementary school children's mathematical instruction. This research can help bridge the existing gap in understanding mathematics. This gap exists due to several variables related to teachers and students. The teachers lack an in-depth knowledge of the syntax of PjBL-based learning and the ability to generate questions that focus on higher-order thinking skills, creative thinking, and problem-solving abilities. Then, students cannot participate in PjBL to foster HOTs, creative thinking, and problem-solving skills due to financial limitations preventing them from purchasing the necessary equipment for project completion. Additionally, limited time allocation and a lack of initiative to independently explore mathematical concepts further hinder their readiness to participate.

In addition, Indonesian students continue to be ranked among the lowest in the world in terms of their academic achievements (Schleicher, 2018). The issue pertains to the findings of a study carried out by the Organization for Economic Cooperation and Development (OECD) using more comprehensive global standards through the Program for International Student Assessment (PISA) test. The study revealed that incorporating this organization has not led to notable progress but has resulted in a lack of growth. The PISA research revealed a decline in Indonesia's literacy, mathematics, and science performance in the last ten years. Specifically, Indonesia ranks 72nd out of 77 nations in literacy, 72nd out of 78 countries in mathematics, and 70th out of 78 countries in science. As a result, Indonesia is currently 74th worldwide (Schleicher, 2018). The findings from the 2022 PISA research indicated that only a small number of Indonesian students demonstrate exceptional proficiency in mathematics at levels 5 and 6 (compared to the OECD average of 9%).

Conversely, only 18% of Indonesian students perform at level 2 (compared to the OECD average of 69%). The average international mathematical literacy scores in PISA 2022 experienced a decline of 21 points. The Indonesian score decreased by 13 points, exceeding the average score worldwide. Among the nations that participated in PISA 2022, 82% witnessed a reduction in their mathematical literacy score compared to PISA 2018 (Kemendikbudristek, 2023; PISA, 2023).

Creativity effectively addresses diverse difficulties, broadening students' perspectives and encouraging them to explore fundamental comprehension (Khalid et al., 2020; Vink et al., 2023). This notion enhances students' cognitive skills and fosters their capacity to critically analyze and evaluate knowledge (Rusilowati et al., 2023; Tanjung et al., 2020). High-order thinking (HOT) encompasses various components, including flexibility, adaptability, and originality (Edwar et al., 2023; Kurniawan et al., 2024). Fluency pertains to the effortless generation of several notions during the creative process. On the other hand, flexibility concerns the capacity to allow go of conventional thinking and incorporate new ideas or alternative approaches. Originality, meanwhile, encompasses the ability to produce ideas that are unexpected, uncommon, or distinctive (Lin, 2021; Newton, 2020).

Creative students are adept at resolving problems. In truth, mathematics classrooms aim to foster a range of skills to enable students to effectively use mathematical concepts in everyday circumstances (Jiang & Li, 2021; Lu & Kaiser, 2022). Hence, an augmentation in creativity will lead to a corresponding enhancement in students' mathematical achievements. The assessment of cognitive domains often follows the revised edition of Bloom's Taxonomy, which involves assessing students' capacity to remember, understand, apply, analyze, evaluate, and generate particular understandings (Adijaya et al., 2023; Cammies et al., 2022). Assessing students' proficiency in problem-solving skills offers valuable information for educators to inform what they believe for future instructional strategies (Son et al., 2020; Suratno et al., 2020).

The project-based learning model can enhance students' creativity in addressing mathematics issues (Hawari & Noor, 2020; Samsudin et al., 2020). The Project-based Learning (PjBL) model is characterized by students engaging in real-world problems, seeking solutions, and collaborating in teams to address challenges (Hujjatusnaini, 2020; Wang, 2023). In the PjBL model, students acquire knowledge of the subject matter and develop their capacity to participate actively in social roles. Skills cultivated in Project-Based Learning (PjBL) encompass effective communication and presentation abilities, adept organizational and time management proficiencies, proficient research and inquiry aptitude, astute self-assessment and reflection capabilities, active discussion in a group, and insightful critical thinking skills.

Implementing the PjBL Model is essential, particularly in teaching mathematics at the elementary school level, given that developing creative thinking and problem-solving skills are not prioritized. PjBL allows teachers to efficiently manage classroom learning by implementing project work that encompasses complex assignments centered on highly demanding inquiries and issues (Lee & Galindo, 2021; Serin, 2023). This method of instruction guides students in designing, problem-solving, decision-making, and conducting investigations and fosters opportunities for independent work (Almulla, 2020; Guo et al., 2020). This idea has been confirmed by Chen et al. (2021), who stated that the teaching model is one of the components that leads to the development of student's ability to think creatively and their capacity to address mathematical issues.

Research demonstrated teacher guidance's efficacy, such as scaffolding techniques, in facilitating student exploration within an atmosphere of student-centered learning (Gunawardena, 2021; Michalsky, 2024). Based on this premise, the researchers came forward with a research question: To what extent does implementing the PjBL model foster creative thinking and problem-solving skills in primary school mathematics learning? The urgency of this study's subject matter was to clarify the improvement of creative thinking and mathematical problem-solving skills through implementing the Project Based Learning (PjBL) instructional method.

Implementing instruction in elementary schools, currently in the concrete operational development stage, strongly connects to the constructivist theory. This theory emphasizes using scaffolding techniques to facilitate learning activities and build comprehension. It involves utilizing the environment and daily life experiences as valuable sources of learning (Jiang et al., 2022; Lafmejani, 2022). Piaget (1936) claims that the cognitive processes of accommodation and assimilation must be moved slowly through classroom instruction. Furthermore, Piaget posits that most interactions are only effective in bringing about cognitive change if positioned at the appropriate level between assimilation and accommodation and carefully build upon the student's existing understanding (Babakr et al., 2019; Pakpahan & Saragih, 2022).

In the field of mathematics instruction, it is widely accepted that achieving a high degree of proficiency in mathematics necessitates a strong level of cognitive ability and independent learning (Rahman et al., 2023); here, the teacher's method of teaching mathematics has to promote effective teamwork and collaborative strategies through class discussions (Setianingsih et al., 2017). In addition, it is crucial to note that using different learning models or techniques can effectively enhance students' motivation for critical thinking and problem-solving skills, leading to improvements in higher-order thinking skills (Hidayati et al., 2020; Rosidin et al., 2019).

Project-based learning (PjBL) is an effective teaching technique in various areas, including mathematics. PjBL incorporates practical concerns, collaborative teamwork, and hands-on exercises to actively engage students in acquiring knowledge (Irdalisa et al., 2024; Sukkeewan et al., 2024). Moreover, students meet real-world problems and obstacles that offer opportunities to use their knowledge and skills. They collaborate constructively with their classmates to solve obstacles by sharing ideas and resources. Students can enhance their comprehension of the subject by engaging in practical activities that provide experiential learning opportunities (Irdalisa et al., 2024; Sukkeewan et al., 2024).

The PjBL facilitates the implementation of effective teaching strategies to enhance learning outcomes and address mathematics challenges for primary school children (Lazić et al., 2021; Syamsuddin et al., 2020). Project-based learning is a trustworthy model that aligns with the educational aims of the twenty-first century. It incorporates creative thinking, communication, and collaboration abilities. The research findings demonstrated this strategy's advantages for students' learning, facilitating useful learning experiences and enhancing their skills (Menggo et al., 2023; Zubaidah et al., 2017). These researchers affirmed that the Project Learning method significantly impacts learning results and student attitudes toward mathematics learning. The findings of this study contributed to the noteworthy finding that the PjBL model generates a favorable influence on learners.

Similar to the studies carried out by Serin (2023) and Widyaningsih and Yusuf (2019), who reported that 21st-century learning necessitates students' ability to adjust, a skill that can be promoted through Project-based Learning (PjBL). The current model advocates for adaptable learning activities that enable students to meet the complexities of real-world situations, using a diverse range of new understandings that they can adapt, modify strategies, and refine their approaches to problem-solving (Kharisma et al., 2019; Zulyusri et al., 2023). Students are expected to be able to navigate a rapidly changing environment where they will encounter challenges that demand adaptation and innovative problem-solving skills. Furthermore, project-based learning intrinsically promotes essential skills such as innovation, analytical reasoning, and autonomy. Students enhance their capacity for critical thinking, analyze facts, and integrate conflicting perspectives through engagement in open-ended projects. They are motivated to think creatively and generate innovative ideas (Junianto & Wijaya, 2019; Meyer & Norman, 2020). Project-based learning is a leading-edge method of instruction that promotes collaboration, analytical reasoning, and problem-solving skills. PjBL encourages enhanced learning, improved knowledge retention, and the cultivation of essential critical skills required in the modern era by involving students in hands-on, authentic projects (Guo et al., 2020; Zulyusri et al., 2023).

PjBL enhances students' comprehension of mathematical concepts and fosters the development of critical thinking abilities through the integration of situations from everyday life, collaborative teamwork, and analytical thinking (Syahriridani et al., 2022; Widyaningsih & Yusuf, 2019). Practical projects in mathematics stimulate students to create a lifelong enthusiasm for the subject by providing them with an expanded understanding of its real-world applications. Project-based learning is a teaching method that can unlock students' capabilities and transform mathematics education by engaging them in meaningful learning opportunities (Purwaningsih et al., 2020; Sahudra et al., 2021).

Project-based learning possesses unique characteristics that set it apart from other learning methods. Correspondingly, Diego-Mantecon et al. (2021) and Lee and Galindo (2021) stated that (1) the content of project-based learning is centered upon students' ideas, specifically in developing their understanding while working on a topic that is meaningful and reflects their interests and experiences;

(2) foster student independence is effective management of assignments and study time; (3) engaging activities that promote problem-solving and finding answers to questions are effective strategies; and (4) the application of productive outcomes aids in the development of learning skills and facilitates the seamless integration of learning, including the utilization of cognitive problem-solving strategies. Moreover, in project-based learning, as articulated by Cheng et al. (2022) and MacLeod and Veen (2020), the components of the process include (1) initiating fundamental inquiries, (2) establishing guidelines for project planning, (3) developing a schedule of activities; (4) monitoring the progress of student projects; (5) assessing student work; and (6) evaluating student learning experiences.

Higher-order thinking skills (HOTS) refer to advanced cognitive abilities essential for analyzing and solving complicated problems, sometimes recognizing numerous or general answers (Munar et al., 2022; Sofiyan et al., 2020). The OECD uses the PISA test to assess students' ability to engage in mathematical reasoning, apply concepts, methods, and facts, and comprehend and predict events (OECD, 2024). The OECD highlights the importance of learners acquiring information literacy abilities. The PISA test focuses on developing higher-order thinking skills (HOT) by including Anderson and Krathwohl's revised Bloom's taxonomy (Morteza & Moghaddam, 2017; Palinussa, 2013).

Mastering concepts in the cognitive aspect differs from ignoring the balance of emotive and psychomotor aspects. In order to be consistent with the 2013 Curriculum, it is important to consider the development of soft skills, including collaborative abilities, mutual respect, a sense of ownership, and a sense of responsibility, throughout the learning process (Amerstorfer & Münster-Kistner, 2021; Roble et al., 2021). High-level thinking meets the requirements of 21st-century education, particularly in the areas of soft skills such as creativity, critical thinking, and innovative thinking. The measured elements in learning encompass scientific creativity, critical thinking, and creative thinking skills (Prastiti et al., 2020; Tanujaya et al., 2021). These qualities are essential in modern education as they promote higher-order thinking skills for students Higher-order thinking results from engaging in critical, creative thinking and solving problems. As observed through the examination of literary creativity, scientific creativity is characterized as an intellectual disposition or capacity to generate or possess the potential to generate distinct and socially or personally valuable results (Albab et al., 2020; Muttaqin et al., 2021).

HOTS promotes the development of fluency, flexibility, and uniqueness as essential attributes of creativity (Aziz, 2021; Suanto et al., 2023). Fluency refers to the quantity of new concepts produced. Flexibility refers to the capacity to adapt and adjust when an existing method or strategy becomes inefficient or impractical. Originality is quantitatively characterized as the uncommonness of an answer, indicating that it only emerges irregularly within a specific group, hence classifying it as original. Every individual can cultivate problem-solving skills and engage in creative thinking, as human cognition is fundamentally connected to patterns of self-regulation. Creativity in creative thinking is crucial for students' success in mathematics (Putri et al., 2020; Wijaya et al., 2021). This idea is because studying mathematics necessitates identifying, resolving, illustrating, examining, synthesizing, and assessing problems (Nizaruddin & Kusmaryono, 2023). Creative thinking skills enhance students' lifelong learning and academic awareness.

2. Research Method

The research was conducted in March-May 2024 at two Elementary Schools in East Manggarai Regency, Indonesia. This quantitative study employs a quasi-experimental design to examine how implementing the PjBL learning model enhances HOTs or creative thinking skills and mathematical problem-solving abilities in primary school children. The selected research design was a quasi-experiment with a pretest-posttest control group design (Creswell, 2014). This study aimed to identify the differences between the experimental and control groups in HOTs or creative thinking and problem-solving skills. The PjBL Model was given to the experimental group in the experiment, whereas the conventional Learning Model was presented to the control group. The conventional model is the lecturing method. This research encompassed three phases: pre-experimentation, experimentation, and post-experimentation.

Before administering the treatment, a pre-test was administered to both groups in order to assess the students' initial ability in problem-solving and creative thinking skills. This was done by having them complete a descriptive test instrument that had been constructed. The pre-test of both groups was analyzed using descriptive statistics to determine the mean of the two groups. The intervention was conducted throughout twelve sessions in both groups in three months, once a week. Subsequently, a posttest was administered to assess how well the pupils performed in creative thinking and mathematical problem-solving. The research sample consisted of 43 children in the sixth grade. The students were selected using a random sampling procedure and divided into two groups from two schools: an experimental group with twenty-two children and a control group with twenty-one students. The research utilized a data-gathering method that employs testing techniques focused on geometry and measurement. The test had ten questions, with five questions assessing creative thinking skills and five items evaluating problem-solving ability.

The research utilized test questions as instruments, divided into two categories: creative thinking skills tests and problem-solving ability tests. Each category employed high-level thinking indicators: questions C4, C5, and C6. This research used a rubric to evaluate and distribute grades based on creative thinking capabilities and problem-solving abilities. The instruments utilized in this study have undergone validation, and their dependability has been empirically confirmed. The reliability coefficient for creative thinking capabilities was 0.79, while the reliability coefficient for problem-solving abilities was 0.80. Both coefficients fell in the high category, as determined by the Alpha-Cronbach formula.

Essay assessments were utilized to gather data on students' creative thinking abilities and quantitative problem-solving skills. Each test consisted of five items. According to Bosch, as cited by Moma (2015), the criteria for innovative thinking capabilities are determined from the numerical range from zero to four. Three experts in mathematics education established the validity of the test instrument in assessing skills in solving mathematical problems. The content validity ratio (CVR) devised by Lawshe was used to verify the accuracy of the instrument's contents (Ndiung et al., 2021).

The study's instruments were validated, and empirical evidence proved that they are reliable. Inter-rater reliability, or the degree of agreement between various raters, was used to calculate the reliability factor of the thinking skills checklist. The reliability coefficient of 0.84 fell within the high range, whereas Cronbach's Alpha calculation was used to determine the coefficient of accuracy for educational results, which came out with a value of 0.81. The data analysis used the method of Multivariate Analysis of Variance (MANOVA), followed by a series of precondition tests, including a normality test for data distribution, homogeneity checks for information class variance, and a multicollinearity analysis. The data analysis was carried out with the help of the SPSS application, version 23.0, which was compatible with the Windows operating system.

3. Results

The hypothesis tested in this research was that the creative thinking skills and mathematical problem-solving abilities of students who received the PjBL model are higher than those who received learning through the conventional learning model. Before the treatment was carried out, both groups were given a pre-test, which can be seen descriptively in Figure 1 below.

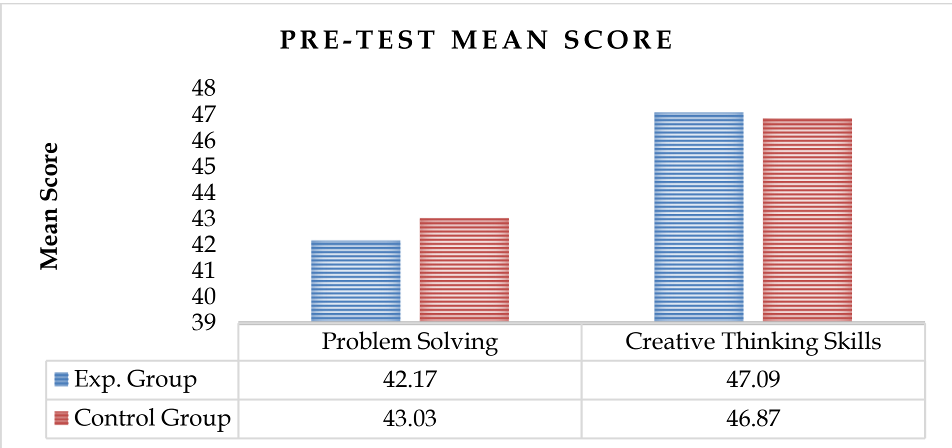

Figure 1: Mean score of the pre-test

Based on the data presented in Figure 1, the average score of both groups before treatment is comparable. Therefore, randomization could be employed to assign respondents to either the experimental or control groups. After being treated for twelve meetings in both groups in three months, experimental and control groups were given a posttest for creative thinking skills and mathematical problem-solving abilities once a week. The results of descriptive statistical analysis of the creative thinking posttest results and students' mathematics learning outcomes can be presented in Figure 2.

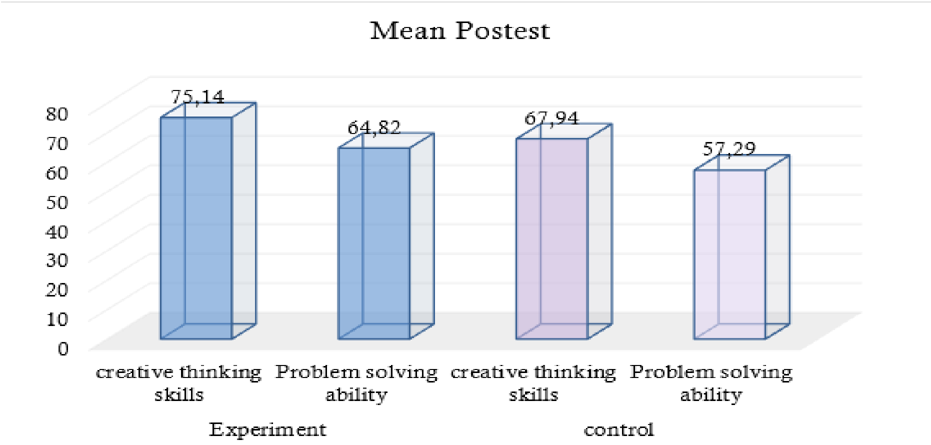

Figure 2: Recap of descriptive of post-test data

Based on the data in Figure 2 above, the average creative thinking and mathematical problem-solving ability of students who received learning using the PjBL model were higher than those who received mathematics learning through conventional teaching models.

From the existing data, proceed with the assumption test, which, in this case, was the data distribution normality test, the data group variance homogeneity test, and the multicollinear test. The results of the assumption test with the help of the SPSS 23.0 program showed that normality had a Kolmogorov sig value exceeding 0.05. Therefore, all groups of students' creative thinking skills scores and mathematical problem-solving ability scores in this study came from a normally distributed population. Then, the homogeneity test of the variance of the creative thinking skills data and the students' mathematical problem-solving ability data was carried out using the Box's covariance matrix equality test to simultaneously test the homogeneity of variance, namely the creative thinking skills group and the students' mathematical problem-solving ability group.

Then, a multicollinearity test was conducted to see the correlation between the variables of creative thinking ability and students' mathematical problem-solving abilities, both dependent variables, and to ensure that the two can be used as different criteria so that there is no overlap. Multicollinearity testing is based on the Variance Inflation Factor (VIF) and tolerance values. The results of the multicollinearity test analysis showed that the VIF value was less than 10. Thus, the variables of creative thinking ability and mathematical solving ability did not experience multicollinearity, so they can be used as different criterion variables. In this case, the two variables could be used as criterion variables separately and simultaneously.

The results showed no multicollinearity, so the procedure continued with hypothesis testing using Multivariate Analysis of Variance (MANOVA). Hypothesis testing was carried out using inferential analysis assisted by the SPSS version 23.0 application program. A recap of the results of the MANOVA analysis of data on students' creative thinking abilities and mathematical problem-solving abilities can be seen in Table 1.

Table 1: Recap of Manova analysis

Multivariate effect	Test[b]	Value	F	Inter group df	Within group df	Sig.
Intercept	Pillai's Trace	.991	5682.327[a]	2.000	41.000	< 0.001
	Wilks' Lambda	.009	5682.327[a]	2.000	41.000	< 0.001
	Hotelling's Trace	115.966	5682.327[a]	2.000	41.000	< 0.001
	Roy's Largest Root	115.966	5682.327[a]	2.000	41.000	< 0.001
PjBL learning model	Pillai's Trace	.260	17.195[a]	2.000	41.000	< 0.001
	Wilks' Lambda	.740	17.195[a]	2.000	41.000	< 0.001
	Hotelling's Trace	.351	17.195[a]	2.000	41.000	< 0.001
	Roy's Largest Root	.351	17.195[a]	2.000	41.000	< 0.001

Note: a: exact statistic; b: design: intercept + learning model

Based on the data in Table 1 above, it was found that the F Wilks' Lambda value = 17.195, and sig < 0.001 with a sig value < 0.05, it can be said that simultaneously the creative thinking abilities and mathematical problem-solving abilities of students who received learning using the Project Based Learning model were higher than students who received mathematics learning through conventional learning models. The PjBL learning model also had a strong and important impact on student's creative thinking and mathematical problem-solving abilities.

4. Discussion

Descriptive data analysis (Figure 2) showed that PjBL students had higher average creative thinking and mathematical problem-solving abilities than conventional math students. This suggests that the PjBL model helps elementary school learners develop creative thinking and mathematics problem-solving capabilities.

The study's results correspond with the research conducted by Karan (2022) and Kim and Kim (2021), who claimed that the Project Learning model impacts primary students' mathematics creative thinking skills. The findings of this study are further confirmed by other research done by Rehman et al. (2023) and Simonton (2021), who demonstrated that the project-based learning (PjBL) method can enhance student engagement in the learning process. This research greatly improves students' comprehension of the provided material. Student engagement can also impact learning outcomes in the final analysis. To prevent the learning process from becoming monotonous and uninteresting, implementing various activities can boost students' comprehension of the learned content. Similarly, the research done by Puccio et al. (2021) and Vink et al. (2023) confirmed that when comparing how well one can think creatively using the

Problem-Based Learning (PBL) model to the ability to think creatively using the Aptitude Treatment Interaction (ATI) model, researchers found that the ATI approach significantly improves the creative thinking ability. Moreover, according to the findings of studies conducted by Benraghda (2022) and Cruz et al. (2023), using PjBL learning and employing uncomplicated instructional aids can effectively enhance the development of critical thinking skills.

This research employed the Project-based Learning (PjBL) method in the experimental class, following a six-step process that develops students' critical thinking skills and enhances their mathematics problem-solving capabilities (Cırıt & Aydemir, 2023; Simonton, 2021; Widiatsih et al., 2020), namely, the first step was Project Determination. At this level, the teacher presented the issue, and then the students engaged in an activity where they asked questions about how to tackle the problem. Second, a strategic plan had to be formulated to complete the tasks. The teacher organized students based on project creation procedures. Students demonstrated their excitement in solving fraction-related problems by actively participating in group activities known as student worksheets. Subsequently, students engaged in problem-solving exercises through interactive discussions and practical encounters with real-world challenges about fractions. Third, a project implementation schedule is created to finish the assignment given. At this stage, the teacher and students collaborate on determining the specific stages and timeline for finishing the project. Once the deadline has been met, students can devise a plan and timetable for its implementation. Fourth, Successful execution of projects with teacher guidance and assistance in completing the task provided. Teachers conduct monitoring to observe student activities during project completion and to assess problem-solving skills. Students execute the implementation using the pre-established project timeline. Fifth, Compile reports and deliver project results through presentations or publications. Teachers and students engage in talks to monitor the progress and achievements of students based on their work outcomes and products. The discussions that are conducted serve as reports, which are utilized as material for presentation to others, and, sixth, the evaluation of the project. At this step, the instructor offers guidance on the project presentation process, followed by a reflective and summarizing discussion on the overall findings derived from the teacher's observation sheet.

Researchers must explicitly outline the limitations of this study, specifically that it solely examined the use of PjBL in developing creative thinking and problem-solving skills in primary school mathematics classes through MANOVA analysis. Undoubtedly, the outcomes of this study will vary if a different method of analysis is employed and a distinct quantity of variables is utilized. Furthermore, this study was only carried out in elementary schools at the fifth-grade level, with a specific emphasis on implementing Project-based Learning (PjBL) to enhance the development of creative thinking and problem-solving skills. Future scholars are expected to explore other variables in the context of teaching mathematics in non-primary schools using alternative approaches.

5. Conclusion and Recommendation

Concerning the findings of the research, a novel alternative can be proposed in the research. This alternative is the interdependence between problem-based learning (PjBL) and the formation and strengthening of the achievement of creative thinking and problem-solving skills in primary school mathematics learning. The Project Based Learning (PjBL) model is a teaching strategy that employs innovative techniques to enable students to effectively address unconventional challenges by engaging in projects that foster creativity and provide concrete student-produced outcomes. The research findings indicate that students who utilize the PjBL learning model showed greater creative thinking skills and problem-solving abilities than students taught mathematics using conventional learning models, separately and simultaneously. The result of this study recommended that elementary school educators employ project-based learning to promote higher-order thinking Skills (HOTs) in sixth-grade children, particularly in geometry and measurement. Hence, further researchers might demonstrate its efficacy in other subject matter or other subjects by conducting further studies.

6. References

Adijaya, M. A., Widiana, I. W., Parwata, I. G. L. A., & Antara, I. G. W. S. (2023). Bloom's taxonomy revision-oriented learning activities to improve procedural capabilities and learning outcomes. *International Journal of Educational Methodology*, *9*(1), 261–270. https://doi.org/10.12973/ijem.9.1.261

Albab, U., Budiyono, & Indriati, D. (2020). Metacognition skills and higher order thinking skills (HOTS) in mathematics. *Journal of Physics: Conference Series*, *1613*(1), Article 012017. https://doi.org/10.1088/1742-6596/1613/1/012017

Almulla, M. A. (2020). The effectiveness of the project-based learning (PBL) approach as a way to engage students in learning. *SAGE Open*, *10*(3), 1–15. https://doi.org/10.1177/2158244020938702

Amerstorfer, C. M., & Münster-Kistner, C. F. V. (2021). Student perceptions of academic engagement and student-teacher relationships in problem-based learning. *Frontiers in Psychology*, *12*, 1–18. https://doi.org/10.3389/fpsyg.2021.713057

Arends, R. I. (2013). *Learning to teach* (9th ed.). McGraw-Hill.

Arici, F. (2023). An examination of the effectiveness of problem-based learning method supported by augmented reality in science education. *Journal of Computer Assisted Learning*, *39*(2), 446–476. https://doi.org/10.1111/jcal.12752

Astuti, P., Qohar, A., & Hidayanto, E. (2019). Proses berpikir siswa dalam menyelesaikan soal higher order thinking skills berdasarkan pemahaman konseptual dan prosedural [Students' thinking process in solving higher order thinking skills questions based on conceptual and procedural understanding]. *Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan*, *4*(1), 117. https://doi.org/10.17977/jptpp.v4i1.11910

Astutik, S., Mahardika, I. K., Indrawati, Sudarti, & Supeno. (2020). HOTS student worksheet to identification of scientific creativity skill, critical thinking skill and creative thinking skill in physics learning. *Journal of Physics: Conference Series*, *1465*(1), Article 012075. https://doi.org/10.1088/1742-6596/1465/1/012075

Aziz, A. A. M. A. (2021). The development of the HOTS mathematical problem-solving framework using the Bar model strategy: A need analysis. *Review of International Geographical Education Online*, *11*(4), 972–981. https://doi.org/10.33403/rigeo.8006811

Babakr, Z. H., Mohamedamin, P., & Kakamad, K. (2019). Piaget's cognitive developmental theory: Critical review. *Education Quarterly Reviews*, *2*(3), 517–524. https://doi.org/10.31014/aior.1993.02.03.84

Benraghda, A. (2022). Self-assessment as a self-regulated learning approach in English oral presentations: College students' choices and perceptions. *Cogent Education*, *9*(1), Article 2123472. https://doi.org/10.1080/2331186X.2022.2123472

Cammies, C., Cunningham, J. A., & Pike, R. K. (2022). Not all Bloom and gloom: Assessing constructive alignment, higher order cognitive skills, and their influence on students' perceived learning within the practical components of an undergraduate biology course. *Journal of Biological Education*, *58*(3), 588–608. https://doi.org/10.1080/00219266.2022.2092191

Chen, J., Kolmos, A., & Du, X. (2021). Forms of implementation and challenges of PBL in engineering education: A review of literature. *European Journal of Engineering Education*, *46*(1), 90–115. https://doi.org/10.1080/03043797.2020.1718615

Cheng, L., Wang, M., Chen, Y., Niu, W., Hong, M., & Zhu, Y. (2022). Design my music instrument: A project-based science, technology, engineering, arts, and mathematics program on the development of creativity. *Frontiers in Psychology*, *12*, 1–8. https://doi.org/10.3389/fpsyg.2021.763948

Cırıt, D. K., & Aydemir, S. (2023). Online scratch activities during the COVID-19 pandemic: Computational and creative thinking. *International Journal of Evaluation and Research in Education*, *12*(4), 2111–2120. https://doi.org/10.11591/ijere.v12i4.24938

Cook, S. C. (2020). Schema-based instruction for mathematical word problem solving: An evidence-based review for students with learning disabilities. *Learning Disability Quarterly*, *43*(2), 75–87. https://doi.org/10.1177/0731948718823080

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). SAGE Publication.

Cruz, S., Lencastre, J. A., & Viseu, F. (2023). Heuristics and usability testing of a project-based learning online course: A case study with structural mathematical concepts. *International Journal of Instruction*, *16*(3), 465–488. https://doi.org/10.29333/iji.2023.16325a

Diego-Mantecon, J. M., Prodromou, T., Lavicza, Z., Blanco, T. F., & Ortiz-Laso, Z. (2021). An attempt to evaluate STEAM project-based instruction from a school mathematics perspective. *ZDM – Mathematics Education*, *53*(5), 1137–1148. https://doi.org/10.1007/s11858-021-01303-9

Edwar, E., Putri, R. I. I., Zulkardi, Z., & Darmawijoyo, D. (2023). Developing a workshop model for high school mathematics teachers constructing HOTS questions through the Pendidikan Matematika Realistik Indonesia approach. *Journal on Mathematics Education*, *14*(4), 603–626. https://doi.org/10.22342/jme.v14i4.pp603-626

Gunawardena, M. (2021). Scaffolding students' critical thinking: A process not an end game. *Thinking Skills and Creativity*, *41,* Article 100848. https://doi.org/10.1016/j.tsc.2021.100848

Guo, P., Saab, N., Post, L. S., & Admiraal, W. (2020). A review of project-based learning in higher education: Student outcomes and measures. *International Journal of Educational Research*, *102,* Article 101586. https://doi.org/10.1016/j.ijer.2020.101586

Handayani, A. D., & Iswantiningtyas, V. (2020). Javanese traditional games as a teaching and learning media to socialize and introduce mathematics since early age. *Journal of Physics: Conference Series*, *1521*(3), 1–7. https://doi.org/10.1088/1742-6596/1521/3/032008

Hawari, A. D. M., & Noor, A. I. M. (2020). Project based learning pedagogical design in STEAM art education. *Asian Journal of University Education*, *16*(3), 102–111. https://doi.org/10.24191/ajue.v16i3.11072

Hidayati, Y. M., Ngalim, A., Sutama, Arifin, Z., Abidin, Z., & Rahmawati, E. (2020). Level of combinatorial thinking in solving mathematical problems. *Journal for the Education of Gifted Young Scientists*, *8*(3), 1231–1243. https://doi.org/10.17478/JEGYS.751038

Hujjatusnaini, N. (2020). The effect of blended project-based learning integrated with 21st-century skills on pre-service biology teachers' higher-order thinking skills. *Jurnal Pendidikan IPA Indonesia*, *11*(1), 104–118. https://doi.org/10.15294/jpii.v11i1.27148

Irdalisa, I., Zulherman, Z., Elvianasti, M., Widodo, W. S., & Hanum, E. (2024). Effectiveness of project-based learning on STEAM-based student's worksheet analysis with ecoprint technique. *International Journal of Educational Methodology*, *10*(1), 123–135. https://doi.org/10.12973/ijem.10.1.923

Jiang, B., & Li, Z. (2021). Effect of Scratch on computational thinking skills of Chinese primary school students. *Journal of Computers in Education*, *8*(4), 505–525. https://doi.org/10.1007/s40692-021-00190-z

Jiang, Y., Xu, N., Xu, S., & Wang, S. (2022). The enlightenment of Piaget's theory to Chinese primary school education. *Advances in Social Science, Education and Humanities Research*, *670*, 878–882. https://doi.org/10.2991/assehr.k.220704.158

Junianto, J., & Wijaya, A. (2019). Developing students' mathematical literacy through problem based learning. *Journal of Physics: Conference Series*, *1320*(1), Article 012035. IOP Publishing. https://doi.org/10.1088/1742-6596/1320/1/012035

Karan, E. (2022). Enhancing students' problem-solving skills through project-based learning. *Journal of Problem Based Learning in Higher Education*, *10*(1), 74–87. https://doi.org/10.54337/ojs.jpblhe.v10i1.6887

Kemendikbudristek. (2023). Laporan PISA Kemendikbudristek [PISA report of the Ministry of Education and Culture]. *PISA 2022 Dan Pemulihan Pembelajaran Indonesia* (pp. 1–25). https://balaibahasariau.kemdikbud.go.id/wpcontent/uploads/2023/12/LAPORAN-PISA-KEMENDIKBUDRISTEK.pdf

Khalid, M., Saad, S., Hamid, S. R. A., Abdullah, M. R., Ibrahim, H., & Shahrill, M. (2020). Enhancing creativity and problem solving skills through creative problem solving in teaching mathematics. *Creativity Studies*, *13*(2), 270–291. https://doi.org/10.3846/cs.2020.11027

Kharisma, F. N., Susilowati, S. M. E., & Ridlo, S. (2019). The effective learning models in developing problem-solving skills. *KnE Social Sciences, 3*(18), 595–604 https://doi.org/10.18502/kss.v3i18.4750

Kim, H. W., & Kim, M. K. (2021). A case study of children's interaction types and learning motivation in small group project-based learning activities in a mathematics classroom. *Eurasia Journal of Mathematics, Science and Technology Education*, *17*(12), em2051. https://doi.org/10.29333/ejmste/11415

Kurniawan, E. S., Mundilarto, M., & Istiyono, E. (2024). Improving student higher order thinking skills using Synectic-HOTS-oriented learning model. *International Journal of Evaluation and Research in Education*, *13*(2), 1132–1140. https://doi.org/10.11591/ijere.v13i2.25002

Lafmejani, A. Q. (2022). Cognitive evolution of the "Human" concept and its adaptation to Piaget's theory. *Caspian Journal of Neurological Sciences*, *8*(4), 222–233. https://doi.org/10.32598/CJNS.4.31.355.1

Lazić, B. D., Knežević, J. B., & Maričić, S. M. (2021). The influence of project-based learning on student achievement in elementary mathematics education. *South African Journal of Education*, *41*(3), Article 1909. https://doi.org/10.15700/saje.v41n3a1909

Leasa, M. (2020). The effect of learning styles on the critical thinking skills in natural science learning of elementary school students. *Elementary Education Online*, *19*(4), 2086–2097. https://doi.org/10.17051/ilkonline.2020.763449

Lee, J. S., & Galindo, E. (2021). Examining project-based learning successes and challenges of mathematics preservice teachers in a teacher residency program: Learning by doing. *Interdisciplinary Journal of Problem-Based Learning*, *15*(1), 1–20. https://doi.org/10.14434/ijpbl.v15i1.28786

Li, Z. (2022). Assessment of scientific thinking and creativity in an electronic educational environment. *International Journal of Science Education*, *44*(3), 463–486. https://doi.org/10.1080/09500693.2022.2032863

Lin, X. (2021). Investigating the unique predictors of word-problem solving using meta-analytic structural equation modeling. *Educational Psychology Review*, *33*(3), 1097−1124. https://doi.org/10.1007/s10648-020-09554-w

Liu, M. (2023). Bayesian optimization and ensemble learning algorithm combined method for deformation prediction of concrete dam. *Structures*, *54*, 981–993. https://doi.org/10.1016/j.istruc.2023.05.136

Lu, X., & Kaiser, G. (2022). Creativity in students' modelling competencies: Conceptualisation and measurement. *Educational Studies in Mathematics*, *109*(2), 287–311. https://doi.org/10.1007/s10649-021-10055-y

MacLeod, M., & Veen, J. T. V. D. (2020). Scaffolding interdisciplinary project-based learning: A case study. *European Journal of Engineering Education*, *45*(3), 363–377. https://doi.org/10.1080/03043797.2019.1646210

Marbán, J. M., Radwan, E., Radwan, A., & Radwan, W. (2021). Primary and secondary students' usage of digital platforms for mathematics learning during the COVID19 outbreak: The case of the Gaza strip. *Mathematics*, *9*(2), Article 110. https://doi.org/10.3390/math9020110

Menggo, S., Pramesti, P. D. M. Y., & Krismayani, N. W. (2023). Integrating project-based learning in preparing students' interpersonal communication skills on speaking courses in Indonesia. *International Journal of Learning, Teaching and Educational Research*, *22*(9), 219–240. https://doi.org/10.26803/ijlter.22.9.12

Meyer, M. W., & Norman, D. (2020). Changing design education for the 21st century. *The Journal of Design, Economics, and Innovation*, *6*(1), 13–49. https://doi.org/10.1016/j.sheji.2019.12.002

Michalsky, T. (2024). Metacognitive scaffolding for preservice teachers' self-regulated design of higher order thinking tasks. *Heliyon*, *10*(2), e2480. https://doi.org/10.1016/j.heliyon.2024.e24280

Moma, L. (2015). Pengambangan instrumen kemampuan berpikir kreatif matematis untuk siswa SMP [Development of mathematical creative thinking instruments for junior high school students]. *Delta-Pi: Jurnal Matematika Dan Pendidikan Matematika*, *4*(1), 27–41. https://doi.org/10.33387/dpi.v4i1.142

Morteza, T., & Moghaddam, M. Y. (2017). On the plausibility of Bloom's higher order thinking strategies on learner autonomy: The paradigm shift. *Asian-Pacific Journal of Second and Foreign Language Education, 2,* Article 14. https://doi.org/10.1186/s40862-017-0037-8

Munar, A., Winarti, W., Nai'mah, N., Rezieka, D. G., & Aulia, A. (2022). Improving higher order thinking skill (HOTs) in early children using picture story book. *AL-ISHLAH: Jurnal Pendidikan*, *14*(3), 4611–4618. https://doi.org/10.35445/alishlah.v14i3.2224

Muttaqin, H., Susanto, Hobri, & Tohir, M. (2021). Students' creative thinking skills in solving mathematics higher order thinking skills (HOTs) problems based on online trading arithmetic. *Journal of Physics: Conference Series*, *1832*(1), Article 012036. https://doi.org/10.1088/1742-6596/1832/1/012036

Ndiung, S., Sariyasa, Jehadus, E., & Apsari, R. A. (2021). The effect of treffinger creative learning model with the use RME principles on creative thinking skill and mathematics learning outcome. *International Journal of Instruction*, *14*(2), 873–888. https://doi.org/10.29333/iji.2021.14249a

Newton, K. J. (2020). Mathematical flexibility: Aspects of a continuum and the role of prior knowledge. *Journal of Experimental Education*, *88*(4), 503–515. https://doi.org/10.1080/00220973.2019.1586629

Nizaruddin, N., & Kusmaryono, I. (2023). Transforming students' pseudo-thinking into real thinking in mathematical problem solving. *International Journal of Educational Methodology*, *9*(3), 477–491. https://doi.org/10.12973/ijem.9.3.477

Nuryadin, A., Karlimah, K., Lidinillah, D. A. M., & Apriani, I. F. (2023). Blended learning after the pandemic: The flipped classroom as an alternative learning model for elementary classrooms. *Participatory Educational Research*, *10*(3), 209–225. https://doi.org/10.17275/per.23.52.10.3

OECD (Organisation for Economic Co-operation and Development). (2024). *PISA results 2022 (Volume III) – Factsheets: Indonesia.* OECD. https://www.oecd.org/en/publications/pisa-results-2022-volume-iii-factsheets_041a90f1-en/indonesia_a7090b49-en.html

Pakpahan, F. H., & Saragih, M. (2022). Theory of cognitive development by Jean Piaget. *Journal of Applied Linguistics*, *2*(2), 55–60. https://doi.org/10.52622/joal.v2i2.79

Palinussa, A. L. (2013). Students' critical mathematical thinking skills and character: Experiments for junior high school students through realistic mathematics education culture-based. *Journal on Mathematics Education*, *4*(1), 75–94. https://doi.org/10.22342/jme.4.1.566.75-94

Piaget, J. (1936). *Origins of intelligence in the child.* Routledge & Kegan Paul.

PISA. (2023). *PISA 2022 results (Volume I and II) – Country notes: Indonesia*. https://www.oecd.org/en/publications/pisa-2022-results-volume-i-and-ii-country-notes_ed6fbcc5-en/indonesia_c2e1ae0e-en.html

Prastiti, T. D., Tresnaningsih, S., Mairing, J. P., & Azkarahman, A. R. (2020). HOTS problem on function and probability: Does it impact to students' mathematical literacy in Universitas Terbuka? *Journal of Physics: Conference Series*, *1613*(1), Article 012003. https://doi.org/10.1088/1742-6596/1613/1/012003

Puccio, G., Lohiser, A., & Seemiller, C. (2021). Understanding convergent thinking: Developing effective critical thinking. In *Creative problem solving: A 21st century workplace skill*. SAGE Publications. https://doi.org/10.4135/9781071865637

Purwaningsih, E., Sari, A. M., Yuliati, L., Masjkur, K., Kurniawan, B. R., & Zahiri, M. A. (2020). Improving the problem-solving skills through the development of teaching materials with STEM-PjBL (science, technology, engineering, and mathematics-project based learning) model integrated with TPACK (technological pedagogical content knowledge). *Journal of Physics: Conference Series*, *1481*(1), Article 012133. https://doi.org/10.1088/1742-6596/1481/1/012133

Putri, N., Rusdiana, D., & Suwarma, I. R. (2020). Enhancing physics students' creative thinking skills using CBL model implemented in STEM in vocational school. *Journal of Physics: Conference Series*, *1521*, Article 042045. https://doi.org/10.1088/1742-6596/1521/4/042045

Rahman, M. S., Juniati, D., & Manuharawati, M. (2023). The quality of mathematical proficiency in solving geometry problem: Difference cognitive independence and motivation. *Pegem Journal of Education and Instruction*, *13*(3), 255–266.

https://doi.org/10.47750/pegegog.13.03.27

Rehman, N., Zhang, W., Mahmood, A., Fareed, M. Z., & Batool, S. (2023). Fostering twenty-first century skills among primary school students through math project-based learning. *Humanities and Social Sciences Communications*, *10*(1), Article 424. https://doi.org/10.1057/s41599-023-01914-5

Roble, D. B., Lomibao, L. S., & Luna, C. A. (2021). Developing students' creative constructs in mathematics with problem-based (PB) and problem posing (PP) tasks. *Canadian Journal of Family and Youth, 13*(2), 82–94. https://doi.org/10.29173/cjfy29672

Rosidin, U., Suyatna, A., & Abdurrahman, A. (2019). A combined HOTS-based assessment/STEM learning model to improve secondary students' thinking skills: A development and evaluation study. *Journal for the Education of Gifted Young Scientists*, *7*(3), 435–448. https://doi.org/10.17478/jegys.518464

Rusilowati, A., Negoro, R. A., Aji, A. P., & Subali, B. (2023). Development of waves critical thinking test: Physics essay test for high school student. *European Journal of Educational Research*, *12*(4), 1781–1794. https://doi.org/10.12973/eu-jer.12.4.1781

Safie, N., & Zakaria, S. (2023). Examining the effectiveness of thinking maps usage by analysing students' achievement in mathematics subject. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, *31*(1), 197–209. https://doi.org/10.37934/ARASET.31.1.197209

Sahudra, T. M., Ary, K. K., Ramadhani, D., Asnawi, A., & Handrianto, C. (2021). The impact of project-based flipped learning model on the technological pedagogical content knowledge skill of prospective teachers. *Sustainability (Switzerland)*, *13*(5), Article 2606. https://doi.org/10.3390/su13052606

Saldo, I. J. P., & Walag, A. M. P. (2020). Utilizing problem-based and project-based learning in developing students' communication and collaboration skills in physics. *American Journal of Educational Research*, *8*(5), 232–237. https://doi.org/10.12691/education-8-5-1

Samsudin, M. A., Jamali, S. M., Zain, A. N. M., & Ebrahim, N. A. (2020). The effect of STEM project based learning on self-efficacy among high-school physics students. *Journal of Turkish Science Education*, *17*(1), 94–108. https://doi.org/10.36681/tused.2020.15

Schindler, M., & Bakker, A. (2020). Affective field during collaborative problem posing and problem solving: A case study. *Educational Studies in Mathematics*, *105*(3), 303−324. https://doi.org/10.1007/s10649-020-09973-0

Schleicher, A. (2018). *PISA 2018 insights and interpretations*. OECD. Available at https://www.oecd.org/content/dam/oecd/en/about/programmes/edu/pisa/publications/national-reports/pisa-2018/PISA%202018%20Insights%20and%20Interpretations%20FINAL%20PDF.pdf

Serin, H. (2023). Teaching mathematics: The role of project-based learning. *International Journal of Social Sciences & Educational Studies*, *10*(2), Article 28. https://doi.org/10.23918/ijsses.v10i2p378

Setianingsih, R., Sa'dijah, C., As'ari, A. R., & Muksar, M. (2017). Investigating fifth-grade students' construction of mathematical knowledge through classroom discussion. *International Electronic Journal of Mathematics Education*, *12*(4), 383–396. https://doi.org/10.29333/iejme/619

Shidqi, L., Trisniawati, T., & Rhosyida, N. (2023). The development of kobatar learning media for learning mathematics in elementary school. *Advances in Mobile Learning Educational Research*, *3*(2), 886–892. https://doi.org/10.25082/amler.2023.02.015

Simonton, K. L. (2021). Project-based learning and its potential in physical education: An instructional model inquiry. *Curriculum Studies in Health and Physical Education*, *12*(1), 36–52. https://doi.org/10.1080/25742981.2020.1862683

Sofiyan, S., Amalia, R., & Suwardi, A. B. (2020). Development of mathematical teaching materials based on project-based learning to improve students' HOTS and character. *Journal of Physics: Conference Series*, *1460*(1), Article 012006. https://doi.org/10.1088/1742-6596/1460/1/012006

Son, A. L., Darhim, D., & Fatimah, S. (2020). Students' mathematical problem-solving ability based on teaching models intervention and cognitive style. *Journal on Mathematics Education*, *11*(2), 209–222. https://doi.org/10.22342/jme.11.2.10744.209-222

Suanto, E., Maat, S. M., & Zakaria, E. (2023). The effectiveness of the implementation of three dimensions geometry KARA module on higher order thinking skills (HOTS) and motivation. *International Journal of Instruction*, *16*(3), 95–116. https://doi.org/10.29333/iji.2023.1636a

Sukkeewan, P., Songkram, N., & Nasongkhla, J. (2024). Development and validation of a reliable and valid assessment tool for measuring innovative thinking in vocational students. *International Journal of Educational Methodology*, *10*(1), 35–44. https://doi.org/10.12973/ijem.10.1.835

Suratno, S., Wahono, B., Chang, C. Y., Retnowati, A., & Yushardi, Y. (2020). Exploring a direct relationship between students' problem-solving abilities and academic achievement: A STEM education at a coffee plantation area. *Journal of Turkish Science Education*, *17*(2), 211–224. https://doi.org/10.36681/tused.2020.22

Syahriridani, M., Susilo, H., & Ibrohim, I. (2022). Developing problem based learning through lesson study. *Journal of Learning Improvement and Lesson Study, 1*(2), 15–22. https://doi.org/10.24036/jlils.v1i2.20

Syamsuddin, A., Juniati, D., & Siswono, T. Y. E. (2020). Understanding the problem solving strategy based on cognitive style as a tool to investigate reflective thinking process of prospective teacher. *Universal Journal of Educational Research*, *8*(6), 2614−2620. https://doi.org/10.13189/ujer.2020.080644

Tamur, M., Ndiung, S., Nurjaman, A., & Jerito, P. (2020). Do differences in measured mathematical abilities moderate the effectiveness of the realistic mathematics education approach? Meta-analysis studies. *Jurnal Math Educator Nusantara*, *7*(1), 13–26. https://doi.org/10.29407/jmen.v7i1.15736

Tanjung, H. S., Nababan, S. A., Sa'dijah, C., & Subanji, S. (2020). Development of assessment tools of critical thinking in mathematics in the context of HOTS. *Advances in Mathematics: Scientific Journal*, *9*(10), 8659–8667. https://doi.org/10.37418/amsj.9.10.91

Tanujaya, B., Prahmana, R. C. I., & Mumu, J. (2021). Mathematics instruction to promote mathematics higher-order thinking skills of students in Indonesia: Moving forward. *TEM Journal*, *10*(4), 1945–1954. https://doi.org/10.18421/TEM104-60

Vink, I. C. D., Hornstra, L., & Kroesbergen, E. H. (2023). Latent profile analysis of working memory: Relations with creativity and academic achievement. *Creativity Research Journal*, 1–17. https://doi.org/10.1080/10400419.2023.2183323

Wang, X. M. (2023). An online progressive peer assessment approach to project-based learning: A constructivist perspective. *Educational Technology Research and Development*, *71*(5), 2073–2101. https://doi.org/10.1007/s11423-023-10257-6

Widiatsih, A., Wardani, D. A. R., Royhana, U., Djamali, F., & Septory, B. J. (2020). The development of mathematical problems based on higher order thinking skills (HOTS) on comparative material by implementing PBL and its effect on the teacher's creative thinking skill. *Journal of Physics: Conference Series*, *1538*(1), Article 012110. https://doi.org/10.1088/1742-6596/1538/1/012110

Widyaningsih, S. W., & Yusuf, I. (2019). The project-based learning model is based on simple teaching tools and critical thinking skills. *Kasuari: Physics Education Journal (KPEJ)*, *1*(1), 12–21. https://doi.org/10.37891/kpej.v1i1.33

Wijaya, T. T., Zhou, Y., Ware, A., & Hermita, N. (2021). Improving the creative thinking skills of the next generation of mathematics teachers using dynamic mathematics software. *International Journal of Emerging Technologies in Learning*, *16*(13), 212–226. https://doi.org/10.3991/ijet.v16i13.21535

Zubaidah, S., Fuad, N. M., Mahanal, S., & Suarsini, E. (2017). Improving creative thinking skills of students through differentiated science inquiry integrated with a mind map. *Journal of Turkish Science Education*, *14*(4), 77–91. https://doi.org/10.12973/tused.10214a

Zulyusri, Z., Elfira, I., Lufri, L., & Santosa, T. A. (2023). Literature study: Utilization of the PjBL model in science education to improve creativity and critical thinking skills. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 133–143. https://doi.org/10.29303/jppipa.v9i1.2555