Vol. 15, No. 02, pp. 1275-1289, 2025 DOI: 10.23960/jpp.v15i2.pp1275-1289

Jurnal Pendidikan Progresif

e-ISSN: 2550-1313 | p-ISSN: 2087-9849

http://jurnal.fkip.unila.ac.id/index.php/jpp/

The Effect of Project-Based Learning on Students' Systematic Thinking Skills in Elementary Mathematics

Ella Irnesari, Syarifudin, & Adi Apriadi Adiansha*

Department of Elementary School Teacher Education Study Program, STKIP Taman Siswa Bima, Indonesia

*Corresponding email: adiapriadiadiansha@tsb.ac.id

Received: 22 May 2025 *Accepted: 13 June 2025* *Published: 16 June 2025*

Abstract: The purpose of this study is to evaluate the effect on the systematic reasoning capacity of elementary mathematics students of the Project-Based Learning (PjBL) model. The study consisted in a quasi-experimental design with an experimental group applying PjBL and a control group using conventional methods. Purposive sampling enabled participants to be chosen from several elementary schools. The Minimum Competency Assessment guided the method of data collecting by means of a systematic thinking skills test. The test consisted in essay questions covering students's capacity to identify patterns, develop plans, investigate conceptual links, and evaluate approaches of problem-solving. An observation notebook was also used to document student participation and activity all through the learning process. Among other statistical tests, paired and independent t-tests let one compare the pretest and posttest scores. From the data, higher posttest scores and statistically significant deviations exposed that students in the PjBL group showed a rather better improvement in systematic thinking than the control group. Additionally, the observation data demonstrated that PjBL students utilized analytical and reflective thought during the project operations, actively participated in peer-based conversations, and increased their participation. Through their connection between mathematical ideas and practical problems, these learning opportunities helped students to develop their structured thinking and evaluation skills. By providing contextual, meaningful, and cooperative learning, the results imply that PjBL is efficient in the evolution of higher-order thinking. In order to improve students' systematic thinking a ability necessary for both academic success and practical problem-solving teachers are therefore advised to include PjBL into mathematics education.

Keywords: project-based learning, systematic thinking, mathematics learning.

To cite this article:

Irnesari, E., Syarifudin, & Adiansha, A. A. (2025). The Effect of Project-Based Learning on Students' Systematic Thinking Skills in Elementary Mathematics. *Jurnal Pendidikan Progresif*, *15*(2), 1275-1289. doi: 10.23960/jpp.v15i2.pp1275-1289.

INTRODUCTION

Early on in the field of education, students' systematic thinking capacities develop under the direction of mathematics. Still, a lot of research have shown that many elementary school students struggle to understand mathematical ideas in a thorough sense and apply them to practical problems (Lailiyah et al., 2021; Maryanto et al., 2023; Sinaga et al., 2023). According to Juniawan et al. (2023), conventional teacher-centered approaches usually limit students' autonomous investigation of mathematical ideas. On the other hand, Guo et al. (2020) carried out another research showing that students who are used to project-based learning approaches have better systematic reasoning capacity than those who just depend on lecture-based approaches.

Particularly in the areas of logical thinking and complexity problem solving, the 2022 PISA assessment findings show that Indonesian students's numeracy literacy is much below expected (OECD, 2023). This limited ability not only prevents students from understanding daily mathematics content such as reasoning through calculations, interpreting data, or solving word problems but also impedes their preparation for higher degrees of education. Garcia et al. (2022) investigated how the lack of innovation in instructional models greatly affects students' poor thinking skills. Amhar et al. (2022) investigated in the meantime how Project-Based Learning (PjBL) might improve student involvement in mathematics education, so developing critical and methodical thinking abilities. Still, there is a research vacuum about how PjBL especially develops systematic thinking abilities in Indonesian elementary school students. Understanding this mechanism will help teachers create more precise teaching plans that directly enhance students' systematic thinking from early age, so confirming not only the overall success of PjBL but also helping teachers in their growth.

One method whose growing focus of research has been project-based learning. This approach lets students learn by means of research projects relevant to real-world events (Adhelacahya et al., 2023; Leasa et al., 2021; Nahar et al., 2022). Many studies including Almulla, 2020; Anazifa et al., 2017; Huang et al., 2023 find that project-based learning not only improves grasp of mathematical ideas but also strengthens systematic thinking and problem-solving abilities. Furthermore, Sumarni et al. (2020) have shown how including Project-Based Learning into elementary-level math education may raise student motivation, so producing more ideal learning results. Although many studies have underlined the advantages of Project-Based Learning (PjBL) in mathematics education, little is known about how this model develops systematic thinking skills in elementary students (Ummah et al., 2019; Zhang et al., 2023). Recent research including those done by (Chistyakov et al., 2023; Mursid et al., 2022; Yustina et al., 2020) have shown that PjBL can help students engaged in project-based activities develop analytical and planning skills as well as help them to solve organised problems. Still, these findings typically show general cognitive improvements or creativity instead of the developmental path of systematic thinking, including the way in which students organize data, sequence steps, and evaluate results over the course of education.

Moreover lacking in empirical data in the context of Indonesian basic education is evidence of how PjBL supports these methodical approaches of thinking. Thus, the goal of this work is to fill in this void by means of an extensive analysis of the particular contributions of PjBL to the acquisition of systematic thinking skills in mathematics education among elementary school students. Research conducted in many developed countries has also shown that Project-Based Learning (PjBL) supports cognitive development, particularly in the development of higher-order thinking (Aydýn & Mutlu, 2023; Sisamud et al., 2023). Though theoretically aligned with important PjBL components including project planning, problem analysis, and solution evaluation systematic thinking skills including structured thinking, logical sequencing, and reflective judgment—are not exactly aligned with key PjBL components (Payoungkiattikun et al., 2022; Wanglang & Chatwattana, 2023). Moreover, the need of more study in this area is highlighted by the fact that few studies have especially looked at how these elements of PjBL help elementary students acquire systematic thinking. Still, few studies look at its effectiveness in the framework of elementary education in Indonesia (Lukitasari et al., 2021; Ningsih et al., 2020; Sari et al., 2023). A lack of teacher skills and limited resources in adjusting this instructional model impedes the application of Project-Based Learning in elementary schools, claims a 2022 Usmeldi et al. study. Therefore, the aim of this study is to find out how much Project-Based Learning can help students in the framework of elementary education in Indonesia to develop their systematic thinking skills, so closing the gap.

Prioritizing students by means of projects requiring autonomous problem-solving and in-depth investigation, Project-Based Learning (Ghosheh Wahbeh et al., 2021; Hawari & Noor, 2020; Mutakinati et al., 2018) Based on research by Hussein (2021), Project-Based Learning gives higher-order thinking skills, problem-solving, and teamwork top priority all of which improve students's systematic thinking.

In mathematics, systematic thinking is also the ability of students to identify patterns, arrange data, and create logical steps for solving problems (Nor & Sihes, 2021; Tirandazi et al., 2024; Yu & Zin, 2023). Students who have systematic thinking abilities are more suited in understanding complex mathematical structures and using concepts in a more flexible way according to a 2022 Subramaniam et al. study. Further research by MacLeod et al. (2020) showed that when learning mathematics, project-based approaches might help students develop more ordered thinking.

Rahman's (2021) research also showed that project-based activities requiring students to plan, analyze, and assess solutions methodically help them to acquire systematic thinking skills. Exploration-based techniques including Project-Based Learning reflect this. These findings align with the studies by Nurfaidah et al. (2023), which underlined the possibilities of a learning environment including project-based challenges to improve students's metacognitive and systematic thinking capacities when addressing mathematical problems. Based on the background and identified research gaps, this study aims to:

1. Analyze the impact of the Project-Based Learning model on students' systematic thinking skills in elementary mathematics learning.
2. Identify the extent to which Project-Based Learning enhances systematic thinking skills compared to conventional teaching methods.
3. Explore the challenges and obstacles in implementing Project-Based Learning in elementary mathematics classrooms.

METHOD

Research Design and Procedures

This quasi-experimental design with a Nonequivalent Control Group Design are was implemented to this research with two groups, i.e an experimental group learning under the Project-Based Learning model and a control group using conventional teaching approach. The degree to which Project-Based Learning improves students's systematic thinking capacity in respect to elementary mathematics education is evaluated using this method. This study applied a quasi-experimental research design with a value-free equivalent control group lacking in significance. The design consisted on two groups: a control group undergoing conventional learning and an experimental group treated with the Project-Based Learning (PjBL) model. After the intervention, both groups received a posttest to evaluate their learning outcomes; a pretest was used to evaluate their starting competency. This study sought to evaluate PjBL's efficacy in raising students' systematic thinking capacity by means of a comparison between the learning gains of the two groups. This method acknowledges the restrictions of random assignment in a real-world classroom and lets one make a useful comparison.

To ensure the exact application of the Project-Based Learning (PjBL) model during the three main phases of this research, the experimental class underwent careful measurements. Under a comprehensive plan, trained observers tracked classroom activities during the intervention to ensure the PjBL approach was implemented in line with its basic ideas that of student-centered inquiry, cooperative learning, and real-world problem solving. This checklist included specific indicators including the degree of student involvement in project planning, group discussion facilitation, and opportunities for students to combine theory with application. While this was going on, the control class maintained its traditional teaching approach that which consists of teacher-led lectures and individual practice drills. Frequent observation and documentation guaranteed the continuous maintenance of variations in instructional strategies, so verifying the comparison of their effects on students' systematic thinking ability. Thus, the obvious difference between the two approaches remained.

Beginning with preparation, which included the development and validation of research instruments by experts, the study was carried out in three phases including the choice of experimental and controlling groups. Before every intervention, a pretest was given to assess students' initial systematic reasoning capacity. During the implementation period, the experimental group worked on a project centered on a contextual mathematical problem concerning environmental data analysis. Over four weeks, the project was carried out with every session lasting almost ninety minutes. Given the project brief, students started their first week of planning. While the last week was devoted to the presentation of project achievements and guided introspection, the second and third weeks were marked by cooperative group work to compile data and create solutions. The project was meant to be relevant and challenging, so encouraging systematic thinking; it required students to find patterns, examine relationships, and assess solution strategies in real-world situations. By means of scaffolding that is, by asking questions, offering comments during group discussions, and guiding theory to practice the teacher actively enhanced the learning process during this process. Through means of student expression of their reasoning process, assessment of their problem-solving strategies, and investigation of alternative approaches, reflection sessions were intended to improve understanding of systematic thinking. Conversely, during the same period the control group received traditional instruction which included lectures and individual exercises in which case Analyzing data from tests, observations, and motivation questionnaires, the Project-Based Learning model was assessed against more traditional approaches; both groups received a posttest.

Specific project tasks were created to develop each ability so that PjBL activities could be directly linked with the targeted systematic thinking indicators. Students' investigation of environmental data trends helped them to develop their ability to spot patterns. Group debates centered on project deliverables and mathematical computation planning helped to shape solution strategies. By tying mathematical ideas like fractions and volume units with real-world environmental consequences, students could examine relationships among concepts. Reflective sessions helped students evaluate solutions by means of justification for their strategies and investigation of substitute approaches. This deliberate alignment clarifies the operationalization of systematic thinking in the PjBL intervention, so building a strong framework for understanding the processes behind its effectiveness and enabling the clear link between measured results and instructional activities.

The next section shows a mapping of important activities in the Project-Based Learning (PjBL) model with the indicators of systematic thinking skills, so clarifying the relationship between the learning intervention and the measured indicators of systematic thinking skills. Every activity deliberately stimulates particular cognitive processes, as the table below shows:

Table 1. Mapping between PjBL activities and systematic thinking skill indicators

Key Activities in PjBL	Systematic Thinking Indicators Targeted	Description
Analyzing environmental data patterns	Identifying patterns	Students analyze volume data of household waste to recognize mathematical patterns in real contexts.
Group discussion to design solution strategies	Designing solution strategies; Analyzing relationships between concepts	Students collaboratively plan steps for calculations and poster design, connecting fractions, volume units, and environmental impact.
Developing educational poster	Applying and synthesizing concepts	Students create posters to communicate their understanding, applying mathematical and environmental knowledge.
Reflection sessions	Evaluating solutions	Students explain their chosen strategies, justify their reasoning, and consider alternative solutions.

Participants

Comprising four parallel classes, the survey covers every fifth-grade student at SDN O'o. Two classes from this population were chosen using a purposive sampling method as research subjects, so producing a total of 60 students 30 in the experimental group and 30 in the control group. While the experimental class was instructed using the Project-Based Learning (PjBL) model, the control class was taught using traditional approaches including lectures and practice activities. The two classes were selected based on their rather similar academic profiles, which were ascertained from first review of most recent report cards of past mathematical performance. This first data set served as the basis for ensuring that the initial skills were similar before the official pretest. With a sample size of 60 students, the necessary statistical tests to assess the effect of the treatment seem adequate.

This study used purposeful sampling to ensure the validity of the research plan. Participants were chosen with deliberate reference to specific criteria. Based on similar pretest results, the selected classes were fifth-grade groups displaying rather equal starting knowledge. Moreover, it was found that if the classroom teachers assigned to both groups had minimum of three years of teaching experience, the instructional model could be applied regularly and successfully. Furthermore, the chosen courses had a similar student count, which helped to reduce any possible bias in data analysis brought about by different class sizes.

Instruments

This paper evaluates systematic thinking skills using a methodical thinking test developed in line with the indicators of systematic thinking in mathematics education (Mundarti & Aldila, 2023). The following are the used investigation tools: Comprising ten essay questions based on the Minimum Competency Assessment, the pretest and posttest instruments in this study consist These tests are meant to evaluate several markers of systematic thinking, including the identification of mathematical patterns, the development of solution strategies, the analysis of conceptual relationships, and the methodical evaluation of problem-solving actions. One essay question, for example, asks students to find a pattern in a series of numbers and explain how they would use that pattern to address a related problem. This evaluation measures pattern recognition as well as the capacity for developing a solution strategy. The Aiken's V values exceeded the 0.70 level, suggesting notable agreement on item relevance, and expert judgment involving mathematics education teachers and seasoned senior teachers established content validity. A Cronbach's Alpha value higher than 0.80 confirmed the test's dependability by pointing out a strong degree of internal consistency. Moreover, student participation was evaluated using a checklist focusing on their ability to create project plans, participate in group discussions, and combine theory with practice during mathematical projects. Using a Likert scale ranging 1 to 5, two separate observers made the observations. Ten items make up the learning motivation questionnaire, which the study also used and was especially meant for this study. Content and reliability validation were applied to this questionnaire; nevertheless, further details on the validation process would help to increase the instrument's legitimacy. On this instrument, scores fell on a five-point Likert scale ranging from strongly disagree to strongly concur. Before and after the intervention, the scale was given to evaluate students' degrees of motivation.

Data Analysis

Different statistical methods will be applied to examine the gathered data in order to ensure the depth and correctness of the research conclusions. Levene's test will be used to show homogeneity of variances between groups; the Kolmogorov-Smirnov method will be used to run normality tests to confirm that the data are generally distributed. The N-Gain score will be calculated and analyzed as showing low, moderate, or high degrees of improvement to assess the effectiveness of the increase in systematic thinking capacities. While paired sample t-tests will examine the variations between pretest and posttest scores inside each group, the independent sample t-test will assess the relevance of variances between the experimental and control groups. In addition to quantitative analysis, qualitative data from questionnaires and observations will be thematically analyzed thematically using simple content analysis techniques, in order to spot trends of student involvement and difficulties applying Project-Based Learning. This approach provides a better knowledge of the learning dynamics that took place during the research and helps to interpret quantitative results in a more whole sense.

■ RESULT AND DISCUSSION

Quantitative Analysis

This study aims to analyze the effectiveness of the Project-Based Learning model in enhancing the systematic thinking abilities of elementary school students. The data were collected from pretest and posttest scores administered to both the experimental and control groups before and after the intervention. Below is a summary of the pretest and posttest results for both groups:

Table 2. Pretest and posttest results of systematic thinking abilities

Group	N	Average Pretest	Average Posttest	Score Difference	N-Gain
Experimental (Project-Based Learning)	30	52.8	80.6	27.8	0.63 (Moderate)
Control (Conventional)	30	53.1	69.2	16.1	0.34 ((Low)

Research results show that the experimental group using the Project-Based Learning (PjBL) paradigm showed a more significant improvement than the control group using traditional learning approaches. Average pretest score in the experimental group was 52.8. After the test, this score rose to 80.6, producing a 27.8 score difference and an N-Gain of 0.63 classified as moderate. By contrast, the average pretest score of the control group was 53.1, which rose to 69.2 in the posttest. The score difference of 16.1 and the low N-Gain of 0.34 follow from this. These findings imply that the PjBL model is noticeably more successful than traditional learning in improving student learning results.

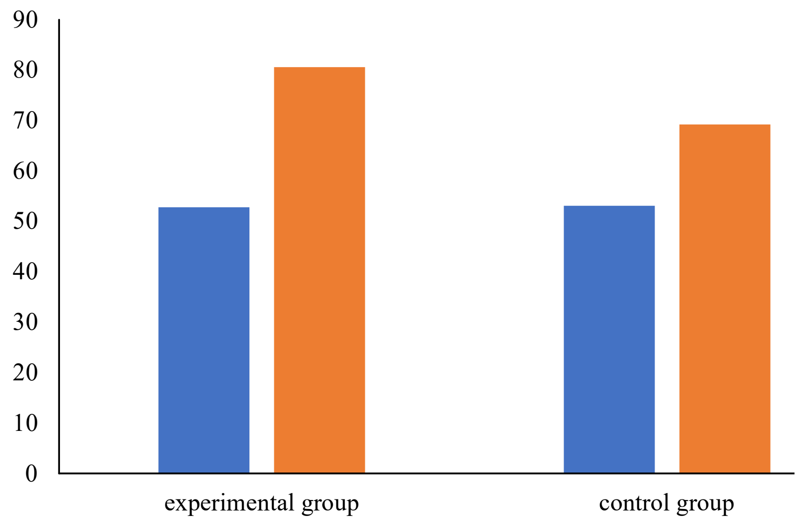

Figure 1. Comparison of pretest and posttest between groups

Figure 1 shows the experimental and control group posttest score variations in relation to N-Gain values. Clearly, the experimental group which followed the Project-Based Learning (PjBL) model saw a posttest score increase of 27.8 points and an N-Gain of 0.63 (moderate category), much higher than the control group that just showed a 16.1-point increase and an N-Gain of 0.34 (low category). This visualization clearly shows the great influence of using PjBL on enhancing students' systematic thinking abilities and clarifies the success of the intervention above that of traditional education.

Before conducting inferential statistical analysis, normality was tested using the Kolmogorov-Smirnov test, and homogeneity of variance was tested using Levene's Test. According to the Kolmogorov-Smirnov normality test results, the pretest and posttest data for both the experimental and control groups exhibit p-values greater than 0.05 (experimental pretest = 0.087; experimental posttest = 0.102; control pretest = 0.092; control posttest = 0.119). This suggests that the data from both groups are normally distributed. Additionally, the homogeneity of variance test, which employs Levene's Test, indicates that the data have homogeneous variances, as evidenced by p-values exceeding 0.05 for both the pretest (p = 0.467) and posttest (p = 0.321). Consequently, the data satisfy the requisite assumptions for parametric statistical analysis. Since the p-values are greater than 0.05 as shown by Table 3 and Table 4, it can be concluded that the data is normally distributed and homogen.

Table 3. Normality test

Group	Pretest (p)	Posttest (p)	Criteria
Experiment (Project-Based Learning)	0.087	0.102	Normal
Control (Conventional)	0.092	0.119	Normal

Table 4. Homogeneity test

Variable l	Levene's Test (p)	Criteria
Pretest	0.467	Homogeneous
Posttest	0.321	Homogeneous

A Paired Sample T-Test was used to ascertain whether there was a substantial improvement within each group between the pretest and posttest. The paired sample t-test results for each indicator of systematic thinking skills indicate that both the experimental group (Project-Based Learning) and the control group (conventional method) experienced substantial improvement. The t-value for identifying mathematical patterns was 9.834 ($p < 0.05$), for designing solution strategies was 10.214 ($p < 0.05$), for analyzing the relationships between concepts was 11.009 ($p < 0.05$), and for evaluating solution steps was 10.673 ($p < 0.05$) in the experimental group. 6.732; 7.012; 7.453; and 7.124 were the t-values for the same indicators in the control group, respectively (all $p < 0.05$). These findings suggest that the experimental group exhibited a statistically significant improvement across all indicators, despite the fact that both groups exhibited an improvement in systematic thinking abilities. This data implies that the implementation of Project-Based Learning is more effective in the development of systematic thinking skills among elementary school pupils.

Table 5. Results of paired sample t-test

Group	t-value	Sig. (p)	Conclusion
Experiment (Project-Based Learning)	11.203	0	Significant
Control (Conventional)	7.561	0	Significant

The posttest results were subjected to an Independent Sample T-Test to ascertain whether there is a substantial difference between the experimental and control groups following the intervention. Statistically significant differences were observed between the experimental group (taught using Project-Based Learning) and the control group (taught using conventional methods) in the posttest results of the independent sample t-test analysis on each indicator of systematic thinking skills. 3.921 ($p < 0.05$) was the t-value for the indicator of identifying mathematical patterns. The t-value was 4.218 ($p < 0.05$) for designing solution strategies, 4.507 ($p < 0.05$) for analyzing the relationships between concepts, and 4.309 ($p < 0.05$) for evaluating solution steps. All indicators of systematic thinking were significantly outperformed by the experimental group in comparison to the control group, as indicated by these results. In comparison to traditional teaching methods, the Project-Based Learning model was demonstrated to be more effective in improving students' systematic reasoning abilities in mathematics.

Table 6. Results of independent sample t-test

Variable	t-value	Sig. (p)	Conclusion
Posttest	4.712	0	**Significant**

Qualitative Analysis

Students in the experimental group who engaged in Project-Based Learning (PjBL) showed a higher degree of motivation and involvement than those in the control group according the results of the qualitative analysis derived from the learning motivation questionnaire and student activity observation forms. PjBL students were noticeably more involved in deep conversations with group members and asked questions of the teacher while developing a math project, such an instructional poster on household waste management including volume calculations. They also showed excitement for linking the idea of fractions with useful measuring tasks. By contrast, students in the control group showed a propensity to passively follow teacher directions and hardly engaged in in-depth conversations. The motivation questionnaire shows that most PjBL students said project-based learning boosted their confidence and sense of challenge in solving mathematical problems. One anonymous student said, "I developed an appreciation for mathematics because I could engage in direct practice and collaborate with others, rather than merely listening." These findings imply that more motivation directly influences the development of systematic thinking, which then raises student involvement. Through group projects including designing strategies, debating problem-solving techniques, and considering project outcomes, students are subtly taught to examine relationships between concepts and methodically assess solutions. These qualitative results thus show how well PjBL mechanisms improve students's systematic thinking. Moreover, by providing a more complete knowledge of the process by which the increased motivation and engagement enabled by active inquiry and cooperation in PjBL are transformed into measurable improvements in particular systematic thinking indicators, including pattern identification, solution strategy design, conceptual analysis, and solution evaluation, these qualitative data improve the quantitative results. This integration highlights the basic processes linking the educational approach to cognitive skill development, so supporting the validity of the research findings.

The Effect of Project-Based Learning on Systematic Thinking

Significant results from the independent t-test and a higher N-Gain score (0.63 vs. 0.34) revealed that the experimental group displayed a better improvement in systematic thinking skills than the control group. Encouragement of active engagement in exploring concepts, participating in discussions, and solving relevant real-world problems pertinent to students' daily life helped the Project-Based Learning (PjBL) model prove successful in developing their systematic thinking ability. Comparatively to those taught with traditional approaches, PjBL group members were more active and cooperative during the learning process and showed greater desire to learn qualitatively. Key elements helping to support the improvement of systematic thinking using this approach were active participation, group projects, and real-life challenges presented in the project.

The findings of this study imply that the Project-Based Learning (PjBL) model significantly influences the improvement of elementary school students's systematic thinking abilities in mathematics education. This result aligns with those of Vistara et al. (2022) and Rushley et al. (2023). This congruence is probably the outcome of the similar traits of PjBL implementation, which gives contextual problem-solving, group projects, and a critical analysis of the learning process top priority. As was also the case in the study carried out by Rushiana et al., students were expected to evaluate and design solutions in real-world problem-based tasks. Vistara et al. underlined how PjBL helps students to improve their analytical and synthetic skills as well as organize their data. Furthermore supporting this is the higher indicators of systematic thinking in this study. The similarity of the student context among elementary-level learners with rather homogeneous academic backgrounds strengthens these consistent results even more. In this study, the most important gains came from the indicators of conceptual relationship analysis and solution step evaluation. This can be attributed to the particular mechanisms in the PjBL design, especially the activities that demanded students to relate mathematical ideas including volume, fractions, and measurement to real-world settings like household waste management. For the design of the educational poster, for example, students were obliged to synthesize a range of data and apply mathematical reasoning, so requiring a great awareness of the interrelationships between many ideas. Furthermore, the organized reflection sessions clearly guided students to assess different strategies and support their chosen ones, so encouraging critical thinking. Since the tasks were not only cognitively demanding but also truly relevant, this resulted in a more marked development of these higher-order indicators in comparison to basic pattern identification or initial strategy planning.

Loyens et al. (2023) indicate that the improved posttest results of the experimental group which was taught using the Project-Based Learning (PjBL) model suggestive of students who were more adept in linking mathematical concepts with real-world scenarios due of their direct participation in authentic and contextual project-based inquiry. Through group projects and the application of theory to practice, this process cognitively prepared students to recognize mathematical patterns during data collecting, develop problem-solving strategies based on previously acquired concepts, and analyze relationships between concepts. The independence given to students in the planning of projects and the independent assessment of solutions improved also the systematic thinking abilities. As these abilities were often evident when students compared various solution approaches and considered the efficacy of strategies used in the project, PjBL had the most effect on the indicators of analyzing conceptual relationships and evaluating solution steps (Wahbeh et al., 2021; Luchang & Nasri, 2023). This was found by examining essay scores per indicator. Though not as noticeably as the other two indicators, the indicators of spotting trends and developing strategies also showed development in the interim. This implies that complex higher-order thinking skills are more influenced by thorough investigation and introspection in PjBL. To support this, recurring trends in student observation and motivation questionnaire responses were thematicly examined in qualitative results. “Deep engagement in collaborative problem-solving” ran across most of them. Students who actively questioned the teacher and each other during group poster building activities clearly displayed this idea. This behavior exactly corresponds with their increasing capacity to examine conceptual relationships. To ensure the consistency of the interpretation, peer validation among researchers was applied. The student’s comment, “I began to enjoy math because I could practice directly and work in groups, rather than simply sit and listen,” shows the important part motivating involvement performed in the improvement of systematic cognitive processing. These cooperative and reflective interactions helped students to critically assess the effectiveness of their chosen solutions, so resulting in the most important posttest score gains in the indicators “analyzing conceptual relationships” and “evaluating solution steps”. Thus, the results confirm that the capacity of PjBL to foster deep thought by means of reflective, real-world, and social learning environments defines its efficacy.

This study shows that one effective approach for improving systematic thinking ability is Project-Based Learning (PjBL). This is so because it provides scaffolding that helps students to complete complex tasks and involves real-world problems that need them to recognize patterns, design strategies, analyze concept relationships, and evaluate solutions (Fitri et al., 2024; Nilada et al., 2024). Group interactions also help students to express and consider their mental processes. Observational data showed PjBL students were more active in trying new strategies and making significant mistakes than students in the control class, who tended to be passive and follow instructions without much investigation. The constructivist theory put forth by Jia et al. (2023), which holds that project-based learning gives students the chance to learn in a social and cooperative environment, helps to clarify this. When students work together to complete a project, they engage in conversations that help them to better understand by means of data analysis, planning, and evaluation of suggested solutions, so strengthening their systematic thinking capacity.

Comparatively to traditional teaching approaches, the Project-Based Learning approach gives more freedom in the investigation of many problem-solving techniques. This is in line with the results of Luchang and Nasri's (2023) Project-Based Learning research, which shows that students who participate directly in the process of solving problems show a more deep understanding of mathematical ideas. Moreover, Nasir et al. (2022) showed that students taught Project-Based Learning are more skillful in using mathematical ideas to fit a range of circumstances than those taught by traditional means.

This study also revealed several difficulties for the successful implementation of Project-Based Learning, including educators' ability to track initiatives and the availability of sufficient financing. Studies by Lestari et al. (2022) which assert that careful application of Project-Based Learning depends on extensive planning and the support of several stakeholders support this. Therefore, teacher preparation is quite essential to guarantee that they may design and implement project-based learning in the best possible form.

This study suggests essentially that elementary school mathematics education has to change its paradigm. If teachers are to help students develop systematic thinking skills, they must employ more interactive and project-based approaches. Project-based learning increases students' motivation, according to 2020 research by Megayanti et al., which so improves their academic performance. Moreover, applying Project-Based Learning could be a smart approach to increase course of instruction student involvement. Lestari and Welyyanti (2022) find that students involved in project-based learning are more motivated to learn since they feel they have control over the learning process. This is consistent with the findings of this study, which reveal that students taught Project-Based Learning models were more involved in the research of mathematical ideas, the posing of questions, and the discussion of them.

This work is therefore a significant contribution to the field of education, especially with regard to the mathematical instruction in primary schools. Project-Based Learning has shown to be an effective teaching tool for improving students' capacity for systematic thinking. Still, more research is required to examine other factors that might influence Project-Based Learning's efficacy, including how technology is used in the process or the creation of more all-encompassing assessment tools to evaluate students' systematic thinking capacity.

■ CONCLUSION

The research results show that the Project-Based Learning approach improves pupils in elementary school mathematics education's systematic thinking abilities. Among students, the Project-Based Learning method produced a significant rise in the depth of knowledge of mathematical ideas, the development of analytical skills, and the methodical problem solving. These findings have practical ramifications since they advise teachers to use Project-Based Learning more often in mathematics classes in order to raise students' critical thinking capacity. Moreover, schools should help Project-Based Learning to be implemented by ensuring the availability of enough tools and giving teachers training.

Future studies should be carried out to find the effectiveness of Project-Based Learning in other mathematical disciplines and to look at its long-term effects on students's systematic thinking development. Future studies could also investigate other elements, such the part technology plays in enabling project-based learning and parent participation in the educational process.

REFERENCES

Adhelacahya, K., Sukarmin, S., & Sarwanto, S. (2023). Impact of problem-based learning electronics module integrated with stem on students' critical thinking skills. *Jurnal Penelitian Pendidikan IPA*. https://doi.org/10.29303/jppipa.v9i7.3931

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

Amhar, A., Sabrina, R., Sulasmi, E., & Saragih, M. (2022). Student critical thinking skills and student writing ability: The role of teachers' intellectual skills and student learning. *Cypriot Journal of Educational Sciences*. https://doi.org/10.18844/cjes.v17i7.7683

Anazifa, R. D., & Djukri, D. (2017). Project-Based learning and problem-based learning: are they effective to improve student's thinking skills? *Jurnal Pendidikan IPA Indonesia*, *6*(2), 346. https://doi.org/10.15294/jpii.v6i2.11100

Aydýn, G., & Mutlu, O. (2023). Project-based learning and flipped classroom model supported project-based learning's impact on academic success, retention, and individual innovation competence. *International Journal of Contemporary Educational Research*, *10*(4(Online First)), 823–833. https://doi.org/10.52380/ijcer.2023.10.4.532

Chistyakov, A. A., Zhdanov, S. P., Avdeeva, E. L., Dyadichenko, E. A., Kunitsyna, M. L., & Yagudina, R. I. (2023). Exploring the characteristics and effectiveness of project-based learning for science and STEAM education. *Eurasia Journal of Mathematics, Science and Technology Education*. https://doi.org/10.29333/EJMSTE/13128

Fitri, R., Lufri, L., Alberida, H., Amran, A., & Fachry, R. (2024). The project-based learning model and its contribution to student creativity: A review. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *10*(1), 223–233. https://doi.org/10.22219/jpbi.v10i1.31499

Ghosheh Wahbeh, D., Najjar, E. A., Sartawi, A. F., Abuzant, M., & Daher, W. (2021). The role of project-based language learning in developing students' life skills. *Sustainability*, *13*(12), 6518. https://doi.org/10.3390/su13126518

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*. https://doi.org/10.1016/j.ijer.2020.101586

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

Huang, W., Li, X., & Shang, J. (2023). Gamified project-based learning: a systematic review of the research landscape. *Sustainability (Switzerland)*. https://doi.org/10.3390/su15020940

Hussein, B. (2021). Addressing collaboration challenges in project-based learning: The student's perspective. *Education Sciences*. https://doi.org/10.3390/educsci11080434

Jia, L., Jalaludin, N. A., & Rasul, M. S. (2023). Design thinking and project-based learning (dt-pbl): a review of the literature. *International Journal of Learning, Teaching and Educational Research*. https://doi.org/10.26803/ijlter.22.8.20

Juniawan, S., Nurhasanah, S., Hadromi, H., Silvia, S., Sapullah Kamali, A., & Widyaningrum, I. (2023). *Meningkatkan minat belajar siswa menggunakan metode pembelajaran konvensional dalam pembelajaran matematika. Metakognisi Jurnal Kajian Pendidikan*, *5*(2), 125–130. https://doi.org/10.57121/meta.v5i2.69

Lailiyah, S., Hayat, S., Urifah, S., & Setyawati, M. (2021). Levels of students' mathematics anxieties and the impacts on online mathematics learning. *Jurnal Cakrawala Pendidikan*, *40*(1), 107–119. https://doi.org/10.21831/cp.v40i1.36437

Leasa, M., Batlolona, J. R., & Talakua, M. (2021). Elementary students' creative thinking skills in science in the Maluku islands, Indonesia. *Creativity Studies*. https://doi.org/10.3846/cs.2021.11244

Lestari, N. A., Hariyono, E., Dwikoranto, D., Prahani, B. K., & Deta, U. A. (2022). Project-based inquiry-science: An innovative learning for thinking, teaching and assessing science-physics. *Momentum: Physics Education Journal*. https://doi.org/10.21067/mpej.v6i1.6254

Lestari, R., & Welyyanti, D. (2022). Implementation of project-based learning for improving a student's ability in analysis, critical thinking and systematic in calculus. *Proceedings of the 4th International Conference on Educational Development and Quality Assurance (ICED-QA 2021)*. https://doi.org/10.2991/assehr.k.220303.044

Loyens, S. M. M., van Meerten, J. E., Schaap, L., & Wijnia, L. (2023). Situating higher-order, critical, and critical-analytic thinking in problem- and project-based learning environments: a systematic review. In *Educational Psychology Review*. https://doi.org/10.1007/s10648-023-09757-x

Luchang, A. L., & Mohamad Nasri, N. B. (2023). Project-based learning (pbl) in enhancing students' higher-order thinking skills (hots): systematic literature review. *International Journal of Academic Research in Progressive Education and Development*, *12*(4). https://doi.org/10.6007/IJARPED/v12-i4/20404

Lukitasari, M., Hasan, R., Sukri, A., & Handhika, J. (2021). Developing student's metacognitive ability in science through project-based learning with e-portfolio. *International Journal of Evaluation and Research in Education*. https://doi.org/10.11591/IJERE.V10I3.21370

MacLeod, M., & van der Veen, J. T. (2020). Scaffolding interdisciplinary project-based learning: a case study. *European Journal of Engineering Education*. https://doi.org/10.1080/03043797.2019.1646210

Maryanto, B. P. A., Rachmawati, L. N., Muhammad, I., & Sugianto, R. (2023). *Kajian literatur/ : problematika pembelajaran matematika di sekolah. Delta-Phi: Jurnal Pendidikan Matematika*. https://doi.org/10.61650/dpjpm.v1i2.94

Megayanti, T., Busono, T., & Maknun, J. (2020). Project-based learning efficacy in vocational education: Literature review. *IOP Conference Series: Materials Science and Engineering*. https://doi.org/

10.1088/1757-899X/830/4/042075

Mohamed Nor, H., & Sihes, A. J. (2021). Critical thinking skills in education: a systematic literature review. *International Journal of Academic Research in Business and Social Sciences*. https://doi.org/10.6007/ijarbss/v11-i11/11529

Mursid, R., Saragih, A. H., & Hartono, R. (2022). The effect of the blended project-based learning model and creative thinking ability on engineering students' learning outcomes. *International Journal of Education in Mathematics, Science and Technology*. https://doi.org/10.46328/ijemst.2244

Mutakinati, L., Anwari, I., & Yoshisuke, K. (2018). Analysis of students' critical thinking skill of middle school through stem education project-based learning. *Jurnal Pendidikan IPA Indonesia*. https://doi.org/10.15294/jpii.v7i1.10495

Nahar, S., Suhendri, Zailani, & Hardivizon. (2022). Improving students' collaboration thinking skill under the implementation of the quantum teaching model. *International Journal of Instruction*. https://doi.org/10.29333/iji.2022.15325a

Nilada, N., Payougkiattikun, W., & Thongsuk, T. (2024). The study of scientific creativity using a project-based learning management model. *International Journal on Social and Education Sciences*, *6*(2), 253–263. https://doi.org/10.46328/ijonses.667

Ningsih, S. R., Disman, Ahman, E., Suwatno, & Riswanto, A. (2020). Effectiveness of using the project-based learning model in improving creative-thinking ability. *Universal Journal of Educational Research*. https://doi.org/10.13189/ujer.2020.080456

Nurfaidah, N., Pujiastuti, E., Nur Cahyono, A., Sugiman, S., Kharisudin, I., & Korkor, S. (2023). Systematic literature review: mathematical creative thinking ability reviewed from self-regulated in Project Based Learning (PjBL) Model. *International Journal of Mathematics and Sciences Education*. https://doi.org/10.59965/ijmsed.v1i1.8

OECD. (2023). PISA 2022 Results (Volume II): Learning During – and From – Disruption, PISA. OECD. https://doi.org/10.1787/a97db61c-en

Payoungkiattikun, W., Intanin, A., Thongsuk, T., & Hemtasin, C. (2022). Project-based learning model to promote preservice science teachers' metacognitive skills. *Journal of Educational Issues*, *8*(2), 576. https://doi.org/10.5296/jei.v8i2.20282

Rahmania, I. (2021). Project based learning (pjbl) learning model with stem approach in natural science learning for the 21st century. *Budapest International Research and Critics Institute (BIRCI-Journal): Humanities and Social Sciences*. https://doi.org/10.33258/birci.v4i1.1727

Rijo-Garcia, S., Segredo, E., & Leon, C. (2022). Computational thinking and user interfaces: a systematic review. *IEEE Transactions on Education*, *65*(4), 647–656. https://doi.org/10.1109/TE.2022.3159765

Rushiana, R. A., Sumarna, O., & Anwar, S. (2023). Efforts to develop students' critical thinking skills in chemistry learning: systematic literature review. *Jurnal Penelitian Pendidikan IPA*, *9*(3), 1425–1435. https://doi.org/10.29303/jppipa.v9i3.2632

Sari, E. D. P., Trisnawati, R. K., Agustina, M. F., Adiarti, D., & Noorashid, N. (2023). Assessment of students' creative thinking skill on the implementation of project-based learning. *International Journal of Language Education*. https://doi.org/10.26858/ijole.v7i3.38462

Sinaga, B., Sitorus, J., & Situmeang, T. (2023).

The influence of students' problem-solving understanding and results of students' mathematics learning. *Frontiers in Education*, *8*. https://doi.org/10.3389/feduc.2023.1088556

Sisamud, K., Chatwattana, P., & Piriyasurawong, P. (2023). The project-based learning using design thinking model via metaverse to enhance buddhism innovators. *Higher Education Studies*, *13*(3), 10. https://doi.org/10.5539/hes.v13n3p10

Sri Mundarti, & Aldila, F. T. (2023). Affective assessment instrument based on krathwohl-anderson taxonomy in senior high school. *Journal Evaluation in Education (JEE)*, *4*(2), 74–79. https://doi.org/10.37251/jee.v4i2.323

Subramaniam, S., Maat, S. M., & Mahmud, M. S. (2022). Computational thinking in mathematics education: A systematic review. In *Cypriot Journal of Educational Sciences*. https://doi.org/10.18844/cjes.v17i6.7494

Sumarni, W., & Kadarwati, S. (2020). Ethno-stem project-based learning: Its impact to critical and creative thinking skills. *Jurnal Pendidikan IPA Indonesia*. https://doi.org/10.15294/jpii.v9i1.21754

Tirandazi, P., Bamakan, S. M. H., & Jahromi, M. J. H. (2024). Systematic thinking approach for analyzing individuals and government impact on covid-19 outbreak in Iran. *International Journal of Information Technology & Decision Making*, *23*(01), 89–106. https://doi.org/10.1142/S0219622023400047

Ummah, S. K., Inam, A., & Azmi, R. D. (2019). Creating manipulatives: Improving students' creativity through project-based learning. *Journal on Mathematics Education*. https://doi.org/10.22342/jme.10.1.5093.93-102

Usmeldi, U., & Amini, R. (2022). Creative project-based learning model to increase creativity of vocational high school students. *International Journal of Evaluation and Research in Education*. https://doi.org/10.11591/ijere.v11i4.21214

Vistara, M. F., Rochmad, R., & Wijayanti, K. (2022). Systematic literature review: stem approach through engineering design process with project based learning model to improve mathematical creative thinking skills. *Mathematics Education Journal*. https://doi.org/10.22219/mej.v6i2.21150

Wan Mohd Nasir, W. M. F., Halim, L., & Arsad, N. M. (2022). Strategies in promoting creative thinking skills in science classroom: A systematic review. *Cypriot Journal of Educational Sciences*. https://doi.org/10.18844/cjes.v17i12.7605

Wanglang, C., & Chatwattana, P. (2023). The project-based learning model using gamification to enhance 21st century learners in Thailand. *Journal of Education and Learning*, *12*(2), 99. https://doi.org/10.5539/jel.v12n2p99

Yu, L., & Zin, Z. M. (2023). The critical thinking-oriented adaptations of problem-based learning models: a systematic review. *Frontiers in Education*, *8*. https://doi.org/10.3389/feduc.2023.1139987

Yustina, Syafii, W., & Vebrianto, R. (2020). The effects of blended learning and project-based learning on pre-service biology teachers' creative thinking skills through online learning in the COVID-19 pandemic. *Jurnal Pendidikan IPA Indonesia*. https://doi.org/10.15294/jpii.v9i3.24706

Zhang, L., & Ma, Y. (2023). A study of the impact of project-based learning on student learning effects: a meta-analysis study. In *Frontiers in Psychology*. https://doi.org/10.3389/fpsyg.2023.1202728