RADIAN Journal: Research and Review in Mathematics Education
Volume 05, No. 01, 2026, pp. 17-30
e-ISSN: 2961 - 7049

The Effect of a Project-Based Learning Model Using Dienes Blocks as Manipulative Media on Improving Understanding of Mathematical Concepts

Subito[1], Ramlan[2], Sunata[3*], Olubunmi Kayode Ayanwoye[4]

[1,2,3*]Elementary School Teacher Education, Universitas Pasundan, Indonesia
[4]Mathematics Education, Federal University Oye-Ekiti, Nigeria
*Correspondence: sunata@unpas.ac.id

Received: 3 January 2026 | Revised: 21 February 2026 | Accepted: 19 March 2026 | Published Online: 30 March 2026

Abstract

This study aimed to determine the differences, effects, and effect size of the Project Based Learning (PjBL) model assisted by Dienes blocks manipulative media on elementary school students' mathematical conceptual understanding. The study employed a quantitative approach using a quasi-experimental method with a nonequivalent control group design. The population consisted of all fifth-grade students at SDN 147 Citarip Barat Bandung in the 2025/2026 academic year. The sample included Class VB as the experimental group and Class VA as the control group, with 27 students in each class. Data were collected through pretest and posttest instruments. The data were analyzed using normality tests, homogeneity tests, Independent Sample T-Test, Paired Sample T-Test, and effect size analysis. The findings revealed a significant difference between students taught using the PjBL model assisted by Dienes blocks and those taught through conventional learning (Sig. 0.049 < 0.05). Furthermore, the implementation of the PjBL model assisted by Dienes blocks had a significant effect on students' mathematical conceptual understanding (Sig. < 0.001). The effect size analysis yielded a Cohen's d value of 0.549, indicating a moderate effect. Therefore, the PjBL model assisted by Dienes blocks is effective in improving elementary school students' mathematical conceptual understanding.

Keywords: Project-Based Learning (PjBL); Dienes Blocks; Mathematical Concept Understanding; Elementary School Students

How to Cite: Subito, Ramlan, Sunata, & Ayanwoye, O. K. (2026). The Effect of a Project-Based Learning Model Using Dienes Blocks as Manipulative Media on Improving Understanding of Mathematical Concepts. *RADIAN Journal: Research and Review in Mathematics Education, 5*(1), 17-30. http://doi.org/10.35706/radian.v5i1.13490

INTRODUCTION

Education is a conscious and planned effort aimed at developing students' potential so that they possess the spiritual, intellectual, and personal qualities, as well as the skills necessary for life in society, as citizens of a nation, and as members of a state. Through education, students are expected to develop the various competencies required to keep pace with advancements in science and technology. One of the key processes in education is learning, which is a process that results in behavioral changes in an individual. According to Dinata and Prihastari (2021, p. 139), learning can transform an individual from being unaware to aware, from being unable to capable, and from not understanding to understanding. These changes encompass various aspects of personality, including cognitive, affective, and psychomotor aspects. In line with this, Suardi, as cited in Herawati (2020, p. 29), states that learning is a change within an individual characterized by the formation of new behavioral patterns in the form of understanding, skills, and attitudes as a result of acquired experiences. Thus, learning is a process that enables students to acquire knowledge and experiences that contribute to their overall development.

The learning process is realized through learning activities that are systematically designed and implemented to achieve educational goals. Komalasari (2015, p. 3) explains that learning is a process that is systematically planned, implemented, and evaluated so that learning objectives can be achieved effectively and efficiently. In practice, learning involves interaction between teachers and students, both directly and through the use of various learning resources and media (Rusman, 2017, p. 84). This corresponds with Vygotsky's social constructivism (Das, 2020), which holds that knowledge is co-constructed through real-world, cooperative actions. Dienes blocks function as mediating instruments in this investigation, bridging the gap between abstract conceptualization and actual manipulation. An effective way to demonstrate why manipulatives improve conceptual knowledge is to follow the evolution from enactive (manipulating Dienes blocks) to iconic (visual representations) to symbolic (mathematical notation). Therefore, teachers are required to be able to create an active, innovative, and meaningful learning environment through the use of learning models, methods, and media that are appropriate for the characteristics of the students.

Mathematics is one of the subjects that plays a crucial role in the education system because it serves to develop logical, systematic, critical, creative, and analytical thinking skills. Daryanto (2013, p. 411) states that mathematics instruction should begin in elementary school so that students develop rational thinking skills and are able to solve various problems in daily life. At the elementary school level, mathematics instruction should be adapted to the cognitive development stage of students, who are still in the concrete operational stage. Therefore, mathematics instruction needs to provide hands-on learning experiences through the use of concrete objects or manipulatives so that abstract concepts can be more easily understood by students (Ramadianti, 2021, p. 94).

One of the primary goals of mathematics education is to develop students' ability to understand mathematical concepts. This ability serves as the foundation for students to grasp more complex material, connect various mathematical concepts, and apply them to problem-solving (Putri & Nasution, 2023). According to Aini et al. (2020), mathematical conceptual understanding includes the ability to restate a concept in one's own words, classify objects based on specific characteristics, provide examples and non-examples, present concepts in various forms of representation, and apply concepts in various problem-solving situations. Thus, students with a strong conceptual understanding will find it easier to grasp mathematical material in depth compared to those who merely memorize formulas or problem-solving procedures.

One of the primary goals of mathematics education is to develop students' ability to understand mathematical concepts. This ability serves as the foundation for students to grasp more complex material, connect various mathematical concepts, and apply them to problem-solving (Afriansyah et al., 2024). According to Aini et al. (2020), mathematical conceptual understanding includes the ability to restate a concept in one's own words, classify objects based on specific characteristics, provide examples and non-examples, present concepts in various forms of representation, and apply concepts in various problem-solving situations. Thus, students with a strong conceptual understanding will find it easier to grasp mathematical material in depth compared to those who merely memorize formulas or problem-solving procedures.

Students' poor understanding of mathematical concepts is generally caused by their tendency to memorize formulas without understanding the meaning of the concepts being studied. According to Sunata et al. (2024), innovative teaching methods are needed to improve students' understanding of mathematical concepts. As a result, students struggle when faced with problems that require reasoning or the application of concepts in different situations. Teacher-centered learning also causes students to be less active in constructing their own knowledge, making the learning experience less meaningful. Globally, learner-centered pedagogies are transforming how students learn during classroom instructions. Ayanwoye et al. (2026a) demonstrated that the integration of information and communication technology-driven pedagogies enhance student engagement and learning outcomes. Complementarily, robotics-enhanced problem-solving instruction fosters conceptual understanding by providing tangible, interactive learning experiences (Ayanwoye et al., 2026b); culturally responsive instructions improve mathematics learning by connecting content to students lived experiences (Falebita et al., 2025); and lesson study and think-pair-share instructions enhance achievement through peer dialogue (Falebita et al., 2022). These learner-centered pedagogies have the potentials to improve pupils' cognitive, affective, and psychomotor ways of learning. These suggest that active, interactive, and contextually relevant pedagogies outperform traditional, teacher-centered approaches. Therefore, a learning model is needed that can actively involve students in the learning process while providing contextual and meaningful learning experiences.

One instructional model that can be used to address these issues is Project-Based Learning (PjBL). According to Wahyuni (2019, p. 294), Project-Based Learning is an instructional model that provides students with the opportunity to acquire knowledge through project-based activities rooted in real-world problems (Rosanti et al., 2025). The PjBL model is an operationalisation of constructivist principles, with students as active builders of knowledge, not passive recipients (Kartikasari et al., 2023). This is in line with Vygotsky’s (1978) zone of proximal development where learners are able to progress through collaborative problem solving with appropriate scaffolding. Complementarily, Bruner’s (1966) theory of representation proposes three modes of conceptual understanding development: enactive, iconic and symbolic. Manipulatives such as Dienes blocks help the transition from concrete to abstract. Such theoretical synergy puts PjBL with Dienes blocks as a pedagogically coherent intervention for elementary mathematics.

Through project-based activities, students are required to design, investigate, solve problems, make decisions, and produce a product as the outcome of their learning. Thus, learning becomes more meaningful because students are actively involved in the process of discovering and constructing their own knowledge. Additionally, PjBL can also enhance students’ critical thinking, creativity, communication, collaboration, and conceptual understanding through authentic learning experiences.

In addition to using appropriate instructional models, learning materials that help students understand mathematical concepts concretely are also necessary. One such material is Dienes blocks. The use of manipulatives is essential to Diénès' philosophy of learning mathematics, and one of his main ideas was embodiment, which combines physical movement with actual or pictorial objects to promote abstraction and generalization (Gningue, 2016). Diénès' theory of learning mathematics, which is based on the principles of dynamic, constructivity, mathematical variability, and perceptual variability, is precipitated on six essential stages: free play, which includes "trial and improvement," playing by the rules, including realizing the benefits of rules; comparison (i.e., comparing games, basic analogy, common structures in games and activities); representation, as a means of visualizing the abstract concepts emerging in the learner's mind; symbolization (i.e., studying the representation in order to capture some elements in symbolic form; and formalization, which deals with providing structural elements like axioms and a framework for proofs (Gningue, 2016).

According to Legi (2021, p. 117), Dienes blocks are manipulative learning materials used to help students understand mathematical concepts concretely through the direct manipulation of objects. The use of Dienes blocks allows students to visualize abstract mathematical concepts, making them easier to understand. Through exploration and manipulation of the materials, students can build their understanding independently and gain a more meaningful learning experience.

Several previous studies have shown that the implementation of Project-Based Learning and the use of Dienes blocks can improve students’ understanding of mathematical concepts. A study by Antoni et al. (2025) demonstrated that the implementation of Project-Based Learning in elementary school mathematics significantly improved students’ conceptual understanding. Research by Pradhana et al. (2024) also revealed that the use of Project-Based Learning supported by manipulative teaching aids can improve learning achievement and mathematical concept understanding among elementary school students. Additionally, Herzamzam et al. (2024) found that the use of Dienes blocks can significantly improve students' learning outcomes and mathematical concept understanding. These research findings indicate that the integration of the Project-Based Learning model with Dienes block manipulatives hold great potential for improving elementary school students' understanding of mathematical concepts.

Based on the above description, this study focuses on the application of the Project-Based Learning (PjBL) model aided by Dienes blocks to the mathematical concept understanding of elementary school students. The research questions in this study are: (1) Is there a difference in mathematical concept understanding between students who use the Project-Based Learning (PjBL) model aided by Dienes blocks and those who use conventional learning? (2) Does the Project-Based Learning (PjBL) model supported by Dienes blocks influence students' understanding of mathematical concepts? and (3) To what extent does the Project-Based Learning (PjBL) model supported by Dienes blocks influence students' understanding of mathematical concepts?

The purpose of this study is to determine the differences in mathematical concept understanding between students who use the Project-Based Learning (PjBL) model aided by Dienes blocks and those who use conventional learning methods; to determine the effect of the Project-Based Learning (PjBL) model aided by Dienes blocks on students' mathematical concept understanding; and to determine the extent of the effect of the Project-Based Learning (PjBL) model supported by Dienes blocks on the mathematical concept understanding of elementary school students.

METHODS

This study employs a quantitative approach using a quasi-experimental research design. The research design utilized is the Nonequivalent Control Group Design, which involves two groups an experimental class and a control class without randomizing the research subjects. In this design, both groups were given a pretest and a posttest; however, only the experimental class received the treatment in the form of the implementation of the Project-Based Learning (PjBL) model aided by Dienes blocks, while the control class received conventional instruction.

The population in this study consists of all fifth-grade students at SDN 147 Citarip Barat for the 2025/2026 academic year. The study sample comprises two classes: Class VB, the experimental class with 27 students, and Class VA, the control class with 27 students, resulting in a total sample size of 54 students. The sample was selected using purposive sampling, taking into account the equivalence of characteristics between the two classes.

The Nonequivalent Control Group Design is presented in Table 1.

Table 1. Nonequivalent Control Group Design

Class	Pretest	Treatment	Posttest

Experimental	O_1	X	O_2
Control	O_3		O_4

Notes:
O_1: Pretest for the experimental class
O_2: Posttest for the experimental class
O_3: Pretest for the control class
O_4: Posttest for the control class
X: Intervention in the form of Project-Based Learning (PjBL) assisted by Dienes blocks.

The research instrument used was a test of mathematical concept comprehension in the form of five essay-type questions that had undergone validity and reliability testing. The test instrument was used to measure students' mathematical concept comprehension before and after the intervention. The material used in this study was the perimeter of squares and rectangles for fifth-grade elementary school students.

Data collection was conducted by administering pretests and posttests to the experimental and control classes. The data obtained were then analyzed using IBM SPSS Statistics version 29. Data analysis began with a normality test to determine whether the data were normally distributed, followed by a homogeneity test to assess the equality of variances between the two groups. After meeting the requirements for parametric testing, an Independent Samples T-Test was conducted to determine the difference in mathematical concept understanding between the experimental and control classes. Next, a Paired Sample T-Test was conducted to determine the effect of implementing the Project-Based Learning (PjBL) model assisted by Dienes blocks on students' mathematical concept understanding in the experimental class. Additionally, an effect size calculation using Cohen's d was performed to determine the magnitude of the effect of the Project-Based Learning (PjBL) model assisted by Dienes blocks on students' mathematical concept understanding.

RESULTS AND DISCUSSION

To determine whether there is a significant difference in the understanding of mathematical concepts between students who participated in Project-Based Learning (PjBL) using Dienes blocks and those who participated in conventional learning, a series of statistical analyses were conducted. These analyses included normality tests, homogeneity tests, hypotheses testing using the Independent Sample T-Test and Paired Sample T-Test, and effect size calculations. The data analyzed were derived from the pretest and posttest results of students in the experimental and control classes.

Results

Table 2 is a summary of the pretest and posttest data on students' mathematical concept comprehension in the experimental and control classes.

Table 2. Summary of Pretest and Posttest Data

Class	Minimum	Maximum	Mean	Std. Deviation

Pretest experimental	14	56	34.93	12.137
Posttest experimental	50	100	80.19	15.613
Pretest Control	12	53	33.74	12.724
Posttest Control	51	100	71.67	15.445

Table 2 shows that the average pretest score for the experimental class was 34.93, with a minimum score of 14 and a maximum score of 56. Meanwhile, the average pretest score for the control class was 33.74, with a minimum score of 12 and a maximum score of 53. The near-equivalence of pretest scores across groups ($\Delta = 1.19$) indicate that the initial abilities of both classes were relatively similar before the intervention was administered, this confirms that the observed posttest difference ($\Delta = 8.52$) is attributable to the intervention rather than pre-existing ability differences. This bolsters confidence in the causal interpretation.

The posttest results show that the experimental class achieved an average score of 80.19, with a minimum of 50 and a maximum of 100, while the control class achieved an average score of 71.67, with a minimum of 51 and a maximum of 100. The increase in the average score for the experimental class was higher than that of the control class. This indicates that the implementation of the Project-Based Learning (PjBL) model assisted by Dienes blocks yields better results regarding students' understanding of mathematical concepts.

Before testing the hypothesis, a normality test was first conducted using the Shapiro-Wilk test to determine whether the data were normally distributed. The decision criterion was that if the significance value was greater than 0.05, the data were normally distributed, as shown in Table 3.

Table 3. Results of the Normality Test

Kelas	Statistic	df	Sig.	Description
Pretest Exsperimental	0.090	27	0.200	Normal
Posttest Exsperimental	0.145	27	0.150	Normal
Pretest Cozntrol	0.111	27	0.200	Normal
Posttest Control	0.144	27	0.161	Normal

Based on Table 3, all pretest and posttest data for both the experimental and control classes have significance values greater than 0.05. Thus, it can be concluded that all research data are normally distributed, thereby meeting one of the requirements for conducting a parametric test.

Following the normality test, a homogeneity test was conducted to determine the equality of variances between the experimental and control classes, with the results in Table 4.

Table 4. Results of the Homogeneity Test

Levene Statistic	*df1*	*df2*	*Sig.*
0.185	1	52	0.669
0.076	1	52	0.784

Based on Table 4, the significance value for the pretest was 0.669 and the significance value for the posttest was 0.784. Both values are greater than 0.05, so it can be concluded that the data have homogeneous variance. Since the data are normally distributed and homogeneous, the hypothesis test was conducted using an independent samples t-test, as shown in Table 5.

Table 5. Results of the Posttest Independent Samples t-Test

Variable	*Sig. (2-tailed)*
Posttest on Mathematical Concept Understanding	0.049

Based on the results of the Independent Samples t-test in Table 5, a significance value (two-tailed) of 0.049 was obtained. Since the significance value is less than 0.05 ($0.049 < 0.05$), H_0 is rejected and H_1 is accepted. Thus, it can be concluded that there is a significant difference between the mathematical concept understanding of students using the Project-Based Learning (PjBL) model assisted by Dienes blocks and students using conventional learning.

Furthermore, to determine the effect of the Project-Based Learning (PjBL) model assisted by Dienes blocks on students' mathematical concept understanding, a Paired Sample T-Test was conducted on the experimental class, with the results shown in Table 6.

Table 6. Results of the Paired Sample t-Test

Variable	Sig. (2-tailed)
Pretest and Posttest Experimental Class	0.001

Based on Table 6, a significance value of 0.001 was obtained. This value is less than 0.05, so H_0 is rejected and H_1 is accepted. Thus, it can be concluded that there is a significant effect of the implementation of the Project-Based Learning (PjBL) model aided by Dienes blocks on students' understanding of mathematical concepts.

To determine the magnitude of the effect of the Project-Based Learning (PjBL) model supported by Dienes blocks on students' understanding of mathematical concepts, an effect size calculation was performed using Cohen's d, w hich is shown in Table 7.

Table 7. Effect Size Test Results

Effect Size	Value
Cohen's d	0.549

Based on Table 7, a Cohen's d value of 0.549 was obtained. According to Cohen's criteria, this value falls into the moderate effect category. The resulted effect size probably reflects a synergistic interaction. PjBL provides the pedagogical structure (authentic problems, collaboration, iteration) and Dienes blocks provide the epistemic tool (concrete representation, manipulability), alone, neither may be sufficient. Project-Based Learning (PjBL) model supported by Dienes blocks meet both the motivational (engagement with projects) and cognitive (abstraction with manipulatives) aspects of learning.

The Cohen's d value of 0.549 suggests that the average student in the experimental group scored higher than the students in the control group. This moderate effect, obtained in a short time, is educationally relevant given the short intervention phase. This suggests that even a short exposure to PjBL with manipulatives can lead to visible gains in conceptual understanding. Therefore, it can be concluded that the Project-Based Learning (PjBL) model supplemented with Dienes blocks has a moderate effect on improving students' understanding of mathematical concepts.

Discussion

Prior to the study, students in Class VB (the experimental class) and Class VA (the control class) were first administered a pretest to assess their initial understanding of mathematical concepts related to the perimeter of squares and rectangles. The pretest results showed that the average score for the experimental class was 34.93, while the average score for the control class was 33.74. The difference in the average scores between the two classes was relatively small, indicating that the students' initial abilities in both groups were at nearly the same level.

After four instructional sessions, students in both classes were given a posttest to measure their understanding of mathematical concepts following different instructional approaches. The experimental class received instruction using the Project-Based Learning (PjBL) model supplemented with Dienes blocks, while the control class received conventional instruction. The posttest results showed an increase in the average scores for both classes. The experimental class achieved an average of 80.19, while the control class achieved an average of 71.67. The higher increase in the experimental class indicates that the implementation of the Project-Based Learning (PjBL) model supported by Dienes blocks yields better results than conventional instruction in enhancing students' understanding of mathematical concepts.

During the implementation of the lessons, the learning process in both classes proceeded smoothly in accordance with the planned instructional steps. However, the characteristics of the instruction applied in each class differed. In the experimental class, students were actively engaged in project-based activities that required them to collaborate, discuss, gather information, and complete tasks related to the lesson material. Additionally, the use of Dienes blocks provided students with the opportunity to manipulate concrete objects, making abstract mathematical concepts easier to understand. Meanwhile, in the control class, instruction was more teacher-centered, utilizing conventional methods that emphasized content delivery and problem-solving exercises.

Based on the posttest data analysis, a significance value of 0.049 was obtained, which is smaller than 0.05. These results indicate that there is a significant difference in mathematical concept understanding between students who learned using the Project-Based Learning (PjBL) model aided by Dienes blocks and those who learned through conventional instruction. Furthermore, the average posttest score for the experimental class was higher than that of the control class, leading to the conclusion that the Project-Based Learning (PjBL) model supported by Dienes blocks is more effective in enhancing students' understanding of mathematical concepts.

The strength of the Project-Based Learning (PjBL) model lies in its ability to create student-centered learning. Through project-based activities, students not only receive information from teachers but also build knowledge through hands-on learning experiences. This process encourages students to think critically, collaborate, solve problems, and connect mathematical concepts to real-world situations. Meaningful learning like this helps students understand concepts more deeply than simply memorizing formulas or problem-solving procedures.

The use of Dienes blocks also makes a significant contribution to improving students' understanding of mathematical concepts. This material helps students visualize abstract mathematical concepts through concrete representations. By directly manipulating Dienes blocks, students can observe relationships between concepts, understand the meaning of a procedure, and discover mathematical concepts through real-world learning experiences. This enables students to more easily explain concepts in their own words, identify examples and non-examples, and apply the concepts they have learned in various problem-solving situations.

The results of the study also indicate that the implementation of the Project-Based Learning (PjBL) model using Dienes blocks has a significant effect on students' understanding of mathematical concepts. This is demonstrated by the results of the Paired Sample T-Test, which yielded a significance value of 0.001, which is less than 0.05. These results prove that there was an increase in students' understanding of mathematical concepts after participating in learning using the Project-Based Learning (PjBL) model supported by Dienes blocks.

The extent of the influence of the Project-Based Learning (PjBL) model supported by Dienes blocks on students' understanding of mathematical concepts was determined through an effect size test. The results showed a Cohen's d value of 0.549, which falls into the moderate category. This value indicates that the effect of the Project-Based Learning (PjBL) model supported by Dienes blocks is not only statistically significant but also has a meaningful impact on mathematics instruction in elementary schools.

These findings align with previous studies indicating that Project-Based Learning enhances student engagement in learning and helps students develop a deeper conceptual understanding. Furthermore, the use of manipulative media such as Dienes blocks has been proven to help students understand abstract mathematical concepts in a more concrete and easily comprehensible way. Thus, the implementation of the Project-Based Learning (PjBL) model supported by Dienes blocks can serve as an effective alternative learning approach to enhance elementary school students' understanding of mathematical concepts.

The result of the current study is consistent with the finding of Ayanwoye et al. (2026b) that active, manipulative, and problem-centered pedagogies, whether high-tech (robotics) or low-tech (Dienes blocks) externalize abstract concepts through tangible interaction, allowing learners to construct meaning through embodied cognition.

Based on the overall research findings, it can be concluded that the Project-Based Learning (PjBL) model supplemented with Dienes blocks has an effect on students' understanding of mathematical concepts. This aligns with the summation of Falebita et al. (2025) who demonstrated that culturally responsive instruction enhances mathematics learning by linking content to students' lived experiences. The PjBL model, with its emphasis on authentic, real-world problems, provides a natural tool for such culturally responsive teaching. The effect observed falls into the moderate category, as indicated by a Cohen's d value of 0.549. Therefore, this learning model is suitable for use as an innovation in mathematics education to help students understand concepts in a more meaningful, active, and contextual manner.

This finding has established the fact that, the growing integration of AI and digital tools in mathematics education (Falebita et al., 2025) does not make physical manipulatives redundant but rather establishes a complementary relationship. Dienes blocks provide a tactile, embodied experience that digital tools cannot fully replicate, while digital platforms provide adaptive feedback and scalability. The collaborative nature of PjBL where students discuss, negotiate and co-construct understanding is similar to the cooperative learning principles behind think-pair-share (Falebita et al., 2022).

CONCLUSION

The results of this study indicate that there is a difference in mathematical concept understanding between students who used the Project-Based Learning (PjBL) model aided by Dienes blocks and those who used conventional instruction. This is evidenced by the average posttest score of the experimental class, which was 80.19, while the average posttest score of the control class was 71.67. Furthermore, the results of the Independent Sample T-Test yielded a significance value of $0.049 < 0.05$, indicating that there is a significant difference between the two groups.

This study also shows that the Project-Based Learning (PjBL) model supported by Dienes blocks has a significant effect on students' understanding of mathematical concepts. This is evidenced by the results of the Paired Sample T-Test, which yielded a significance value of $0.001 < 0.05$. The magnitude of the effect of the Project-Based Learning (PjBL) model supported by Dienes blocks on students' understanding of mathematical concepts falls into the moderate category, as indicated by the effect size test result using Cohen's d of 0.549.

This study adds to the continuing discussion on the effectiveness of manipulatives in mathematics education. While some meta-analyses report modest effects for manipulatives, the present results suggest that the pedagogical context in which manipulatives are employed is important. Manipulatives alone may not be sufficient; but manipulatives embedded within inquiry-driven, collaborative, project-based instruction appear to yield meaningful gains. The results suggest the development of a Synergistic Conceptual Development Model where: (1) PjBL, through authentic problems and collaborative structures, stimulates motivation; (2) Dienes blocks provide concrete representations that externalize abstract concepts; (3) the interaction between PjBL and Dienes blocks creates iterative cycles of exploration, reflection and abstraction; and (4) this process improves conceptual understanding. Thus, the Project-Based Learning (PjBL) model supported by Dienes blocks can serve as an effective alternative learning method to enhance elementary school students' understanding of mathematical concepts.

Acknowledgments

We would like to appreciate all the subjects used in this study.

Declarations

Author Contribution	:	Author 1: Conceptualization, Writing - Original Draft, Editing and Visualization, Formal analysis, and Methodology; Author 2 & 3: Writing - Review & Editing, Validation and Supervision; Author 4: Strengthening the theoretical framework, Recommending relevant international references, Enhancing the discussion and interpretation of the findings, and Offering constructive recommendations to increase its international quality and impact.
Funding Statement	:	-
Conflict of Interest	:	The authors declare no conflict of interest.
Generative AI Statement	:	This paper was assisted by AI tools, including ChatGPT for translation, text refinement, and coherence enhancement, as well as Grammarly for proofreading. These tools were used to improve readability and adherence to academic standards. The authors are fully responsible for the content and interpretations presented.
Additional Information	:	Additional information is available for this paper.

REFERENCES

Afriansyah, E. A., Nurjamilah, E., Sumartini, T. S., Hamdani, N. A., & Maulani, G. A. F. (2024, November). Students Mathematical Understanding of Social Arithmetic in Terms of Student Self-Efficacy. In *4th International Conference on Education and Technology (ICETECH 2023)* (pp. 691-708). Atlantis Press.

Aini, N., Hariyani, M., & Suwanti, V. (2020). Analisis kemampuan pemahaman konsep matematika siswa sekolah dasar. *Jurnal Pendidikan Matematika, 4*(2), 112–120.

Amelia, P., Alim, J. A., & Antosa, Z. (2024). Pengaruh model Project Based Learning terhadap kemampuan pemahaman konsep matematika siswa sekolah dasar. *Jurnal Cendekia: Jurnal Pendidikan Matematika, 8*(1), 455–466.

Ayanwoye, O. K., Falebita, O. S., Ambode, A. B., Ogunjobi, A. O., Olubamise, D. B., & Ogundana, E. A. (2026b). From algorithms to innovation: Pre-service mathematics teachers' perceptions of robotics-enhanced problem-solving instruction. *Educational Technology Quarterly*. https://doi.org/10.55056/etq.1089

Ayanwoye, O. K., Okorie, N. C., Falebita, O. S., Akinola, O. T., Ogunjobi, A. O., Okoh, O. M., Ojo, B. A. Y., & Aremu, B. V. (2026a). Evaluating integration of information and communication technology-driven pedagogies in Ekiti state government technical colleges. *Interdisciplinary Educational Technology*, *2*(1), e106. https://doi.org/10.71176/interedtech/17879

Bruner, J. S. (1966). *Towards a theory of instruction.* Cambridge: Harvard University Press.

Daryanto. (2013). *Inovasi pembelajaran efektif*. Yrama Widya.

Das, K. (2020). Realistic mathematics and Vygotsky's theories in mathematics education. *Shanlax International Journal of Education*, *9*(1), 104-108. DOI: https://doi.org/10.34293/education.v9i1.3346

Dinata, R., & Prihastari, E. B. (2021). Teori dan konsep belajar dalam pembelajaran. *Jurnal Pendidikan Dasar, 5*(2), 135–142.

Falebita, O. S., Ayanwoye, O. K., & Salami, O. O. (2022). Effects of lesson study and think-pair-share instructional strategies on students' academic performance in circle geometry. *ABACUS (Mathematics Education Series).47*(2), 140-156. https://www.man-nigeria.org.ng/issues/ABA-EDU-2022-25.pdf

Falebita, O. S., Ayanwoye, O. K., Olofin, S. O., Salami, O. O., Omotoye, O., Akinwamide, C., Ayodeji, M., Ojo, A. A., & Monalisa, L. (2025). Culturally responsive geometry instructions in secondary school: Perspectives of in-service mathematics teachers. *The International Journal of Diversity in Education, 29*(1), 1-25. DOI: https://doi.org/10.18848/2327-0020/CGP/v26i01/1-25

Fisher, D., Lestyorini, R. D., & Fikri, S. T. (2024). Pembelajaran luas trapesium berbantuan GeoGebra tentang pemahaman konsep. *Jurnal Pendidikan Surya Edukasi (JPSE)*, *10*(2), 172-181.Herawati. (2020). *Teori belajar dan pembelajaran*. Penerbit Lakeisha.

Gningue, S. M. (2016). Remembering Zoltan Dienes, a maverick of mathematics teaching and learning: Applying the variability principles to teach algebra. *International Journal for Mathematics Teaching and Learning,* *17*(2). www.cimt.org.uk/ijmtl/index.php/IJMTL/articl e/download/17/13

Herzamzam, D. A., Fauzi, M., & Rahmawati, N. (2024). Penggunaan media blok Dienes dalam meningkatkan hasil belajar matematika siswa sekolah dasar. *Jurnal Pendidikan Dasar Indonesia, 9*(2), 145–154.

Kartikasari, N., Rahman, S., & Ahyan, S. (2023). Model Project-Based Learning untuk Meningkatkan Aktivitas dan Hasil Belajar Siswa melalui Kegiatan Lesson Study. *Plusminus: Jurnal Pendidikan Matematika*, *3*(2), 289-298. https://doi.org/10.31980/plusminus.v3i2.1344

Komalasari, K. (2015). *Pembelajaran kontekstual: Konsep dan aplikasi*. Refika Aditama.

Legi, H. (2021). Pemanfaatan blok Dienes sebagai media manipulatif dalam pembelajaran matematika sekolah dasar. *Jurnal Pendidikan Dasar, 12*(1), 117–124.

Manek, H. (2023). Peningkatan hasil belajar matematika siswa dengan menggunakan media blok Dienes pada materi operasi penjumlahan bilangan cacah. *FRAKTAL: Jurnal Matematika dan Pendidikan Matematika, 4*(1), 1–11.

Pradhana, A., Nugroho, S., & Wulandari, R. (2024). Penerapan model Project Based Learning berbantuan alat peraga manipulatif untuk meningkatkan pemahaman konsep ruas garis bangun datar pada siswa kelas II sekolah dasar. *Jurnal Pendidikan Dasar, 15*(2), 78–89.

Putri, A., & Nasution, E. Y. P. (2023). Kemampuan pemahaman konsep matematis siswa MTs dalam menyelesaikan masalah matematika pada materi bentuk aljabar. *Plusminus: Jurnal Pendidikan Matematika*, *3*(1), 127-138. https://doi.org/10.31980/plusminus.v3i1.1229

Rahayuningsih, S., & Pantiwati, Y. (2025). Efektivitas Project Based Learning pada materi bangun datar terhadap pemahaman konsep matematika siswa. *Jurnal Pendidikan Matematika Indonesia, 10*(1), 25–34.

Ramadianti, N. (2021). Pembelajaran matematika berbasis pengalaman konkret pada siswa sekolah dasar. *Jurnal Pendidikan Guru Sekolah Dasar, 6*(1), 90–98.

Rosanti, R., Satriawati, G., & Putri, F. M. (2025). Model pembelajaran project-based learning terhadap kemampuan representasi matematis siswa materi statistika. *Jurnal Inovasi Pembelajaran Matematika: PowerMathEdu*, *4*(2), 435-448. https://doi.org/10.31980/pme.v4i2.2891

Rusman. (2017). *Belajar dan pembelajaran berorientasi standar proses pendidikan*. Kencana.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Wahyuni, S. (2019). Implementasi Project Based Learning dalam meningkatkan aktivitas dan hasil belajar siswa. *Jurnal Pendidikan, 20*(3), 290–298.