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Implementation of Zoltan P. Dienes' stages of mathematics learning in elementary school education

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Abstrak

Mathematics is an important subject taught at every level of education because it plays a significant role in developing logical, critical, and systematic thinking skills. However, in the learning process at the elementary school level, many students still perceive mathematics as a difficult and less interesting subject. Therefore, an appropriate learning approach is needed to help students understand mathematical concepts in a more concrete and meaningful wayThis study aims to examine the application of Zoltán P. Dienes' learning theory in mathematics learning at the elementary school level. The method used in this research is a qualitative method with a literature study approach. The data were obtained from various sources such as books and scientific journal articles, by analyzing 38 relevant articles related to mathematics learning and the use of learning media. The results of the study show that Dienes' learning theory emphasizes learning through play activities and the use of concrete objects so that students can understand mathematical concepts gradually from concrete to abstract. The stages of learning according to Dienes include free play, games with rules, searching for commonalities, representation, symbolization, and formalization. The implementation of these stages through learning media and educational games can increase students' learning motivation, engagement, and understanding of mathematical concepts. Thus, Dienes' theory can be an effective alternative strategy for mathematics learning that is in accordance with the cognitive development of elementary school students.
Keywords: Mathematics Learning, Dienes' Learning Theory, Learning, Implementation.

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Introduction

Mathematics is a field of knowledge that offers numerous benefits in everyday life (Pangestu & Sutirna, 2021). It is also a subject taught at all levels of education, from elementary and secondary schools to higher education (Fitri, 2023). Furthermore, mathematics education at the elementary school level is an important area for further development, as children at this age are undergoing significant changes in their thinking and learning processes (Anggraini, 2021a). Therefore, mathematics is taught at every educational level to help students apply mathematical concepts in their daily lives (Meidianti dkk., 2022).

Mathematics is a compulsory subject for all students, beginning in elementary school and continuing through subsequent levels of education (Wijayanti & Yanto, 2023). This is because mathematics plays an important role in the development of science and technology and is often regarded as a fundamental discipline underpinning advances in both fields (Meilindawati dkk., 2023). In line with this perspective, the National Council of Teachers of Mathematics (NCTM, 2000) identifies several goals of mathematics education: (1) developing mathematical communication, (2) learning to think mathematically, (3) solving mathematical problems, (4)

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making connections among mathematical ideas, and (5) developing positive attitudes toward mathematics (Marfu'ah dkk., 2022). Thus, mathematics education equips individuals with the ability to engage in abstraction, analyze problems, and apply logical reasoning (Jayantika & Andini, 2022).

Furthermore, mathematics learning is an interactive process between teachers and students that aims to develop logical thinking through learning models designed by teachers. Appropriate teaching methods can support the effective and optimal development of mathematics learning, enabling students to learn more efficiently (Widayati, 2022). Mathematics is also a compulsory subject in elementary schools. Its content consists of interconnected concepts and is closely related to other subjects taught at this level (Anitra, 2021). Therefore, mathematics instruction should emphasize the connections between mathematical concepts and students' everyday experiences (Sohilait, 2021a). Mathematics is considered an important subject because schools expect students to develop systematic and critical thinking skills, confidence, and accuracy (Hamzari dkk., 2024).

Furthermore, mathematics education contributes to the development of knowledgeable and responsible individuals. As a universal discipline that underpins the advancement of modern technology, mathematics plays an important role across various fields and contributes to the development of human reasoning (Prasetya dkk., 2021). As a foundational discipline, mathematics is essential in the learning process. Mathematical learning and critical thinking are closely related, as critical thinking encourages students to work through problems step by step before progressing toward more advanced levels of reasoning (Rahmaini & Chandra, 2024). In other words, mathematics learning should not focus solely on computational skills. Students should also be able to solve problems through logical and critical reasoning. These problems may arise in everyday situations and require mathematical literacy skills (Hayati & Jannah, 2024). Ultimately, mathematical understanding not only helps children succeed in school but also prepares them to face real-world challenges with confidence and competence (Ansya dkk., 2024).

Learning is an instructional approach designed to accommodate the diverse needs of students through differentiated instruction (Maulidiawati & Darmawan, 2024). In elementary education, learning approaches can help address students' learning needs, as reflected in improved learning outcomes, greater classroom engagement, and enhanced critical thinking skills. A literature review is a research method used to collect information and sources on a particular topic from various materials, including journals, books, internet resources, and other relevant literature (Pebriyanti, 2023).

Throughout the learning process, teachers play an important role as facilitators who provide students with meaningful learning experiences to improve their outcomes in terms of knowledge, skills, and attitudes. These competencies serve as essential foundations for students as they prepare for future challenges (Yusro & Ardania, 2023). In line with this perspective, differentiated instruction is one of the approaches associated with the *Merdeka Belajar* curriculum in Indonesia. This approach reflects a student-centered learning philosophy in which instruction is designed, implemented, and assessed to address individual learning needs by considering students' readiness, interests, and learning profiles. Differentiated instruction should therefore be grounded in an understanding of students' learning needs and how teachers respond to them (Marantika dkk., 2023).

In differentiated instruction, teachers deliver learning materials by considering students' levels of readiness, interests, and learning styles. However, teachers have traditionally tended to use conventional teaching methods that emphasize a teacher-centered approach rather than student-centered learning (Barlian dkk., 2023). Differentiated instruction can help increase students' learning motivation, which is an important factor influencing active participation, persistence, and academic achievement. Nevertheless, many students experience low learning motivation due to internal factors, such as limited interest and self-confidence, as well as external factors, including less engaging teaching methods and an unsupportive learning environment (Gymnastiar, 2024)

Furthermore, differentiated instruction has been implemented with support from the *Platform Merdeka Mengajar*, which serves as a source of reference and inspiration for educators. Differentiated instruction can be implemented in four areas: learning environment, content, process, and product (Manzis, 2024). This approach aligns with the broader goal of quality-oriented educational development, which seeks to enable all children to acquire relevant knowledge (*learning to know*), adapt to rapidly changing societies through their work and contributions (*learning to do*), respond to failure, conflict, and crises, and address complex twenty-first-century challenges by applying their cognitive skills (*learning to be*). It also encourages students to collaborate and compete constructively with diverse groups across different professional and social settings, while adapting to changing circumstances to achieve higher levels of competence (*learning to live together*) (Marantika dkk., 2023).

Furthermore, the development of school-level curricula reflects the autonomy of educational institutions, providing them with broad opportunities to develop their own operational curricula according to their specific needs and characteristics (Barlian dkk., 2023). Differentiated instruction is one approach that can address students' learning needs by considering their readiness, interests, and learning profiles (Avandra, 2022). Previous studies have concluded that differentiated instruction is an effective approach to creating inclusive learning experiences that respond to the diverse needs of students (Koimah dkk., 2024). In Indonesia, its implementation has become increasingly important following the adoption of the *Kurikulum Merdeka*, which emphasizes flexible learning tailored to students' individual needs (Koimah dkk., 2024).

On the other hand, the implementation of learning models may involve combining online and face-to-face instruction, commonly referred to as blended learning. This approach encompasses planning and evaluation, as well as the consideration of supporting and inhibiting factors (Zahara dkk., 2022). Blended learning is expected to address learning difficulties arising when direct interaction between teachers and students is not possible or when face-to-face instruction is subject to limitations (Maskur dkk., 2021). In addition, the digital era has brought significant changes to how people learn, teach, interact, and access information (Verawati dkk., 2023). Accordingly, the implementation of e-learning has brought about a paradigm shift in education, presenting various challenges, limitations, and advantages (Verawati dkk., 2023).

Although educational goals have been clearly established, elementary students' mathematics learning outcomes continue to show significant disparities (Satriana dkk., 2025a). Addressing this issue requires encouraging students to enjoy mathematics and develop positive attitudes toward the subject. As facilitators, teachers need teaching methods and strategies that increase students' interest in participating in learning activities. These methods should go

beyond presenting and explaining content by incorporating games relevant to the mathematical concepts being taught (Fatonah & Naemah, 2022). Furthermore, elementary mathematics education introduces fundamental concepts and basic mathematical content that help students understand more advanced material at subsequent educational levels (Rahmania dkk., 2025). Mathematics is therefore a subject taught from elementary school through higher education (Dwiyono & Tasik, 2021).

Applying learning theories proposed by educational experts can greatly assist elementary school teachers in implementing instruction that aligns with the characteristics of each theory (Wahyuningsih & Suranti, 2024). In this regard, Bruner and Dienes emphasized that mathematical concepts and principles can be understood more effectively when presented in concrete forms (Pinem dkk., 2023). Similarly, the discovery method in mathematics learning is intended to encourage students to understand mathematical facts and relationships that are new to them, such as patterns, properties, and specific formulas (Warpaatun, 2023). In addition, the appropriate use of instructional media, particularly manipulatives, is a significant external factor influencing students' mathematics learning outcomes (Herzamzam dkk., 2024).

Many students perceive mathematics as difficult, boring, and exhausting, leading them to regard it as a frightening subject (Ramadhanti & Marhadi, 2024). Several factors contribute to students' fear and dislike of mathematics, one of which is its abstract nature (Firmansyah, 2024). However, mathematics learning is an interactive process between teachers and students that involves developing thinking patterns and processing information within a learning environment deliberately created by teachers through various instructional methods and models (Nengsih, 2022). To ensure the quality of instructional media in the learning process, teachers need to select and plan the use of appropriate and effective media (Yudiyanto dkk., 2023).

Low mathematics learning outcomes are often associated with students' perceptions that mathematics is difficult, complicated, and boring (Nuroktaliya, 2023). Mathematics education can therefore be understood as a process of providing students with learning experiences through a series of planned activities, enabling them to develop competencies related to the mathematical content being studied (Pitasari dkk., 2024). To achieve the intended learning objectives, teachers must plan and implement instruction based on learning theories and developments in educational practice (Arjudin dkk., 2025). Through mathematics learning, students are expected to master a defined set of competencies (Jannah, 2023). This expectation reflects the nature of mathematics as a structured body of knowledge in which properties and theories are developed deductively from defined and undefined elements, axioms, and properties or theories that have been proven true (Kusanti, 2022).

Method

This article employs a qualitative approach using a literature review method. This approach enables researchers to obtain information about related variables and hypotheses used in previous studies (Adlini et al., 2022). In this study, the researchers examined and analyzed 75 articles from national journals relevant to the research topic, particularly those addressing digital technology, learning digitalization, and mathematics education. The data used in this article are secondary data obtained from relevant literature and references, including books and previous research studies. The journal articles serving as the primary sources for this review were retrieved from various national and international platforms, including ScienceDirect,

Emerald Insight, ResearchGate, Google Scholar, Elsevier, Atlantis Press, Sinta Kemdikbud, and other relevant sources.

The review process began with reading the selected articles, followed by reviewing and analyzing their contents to identify their relevance to the issues discussed in this article. The findings were then described and synthesized to draw conclusions. Data analysis involved organizing the data, elaborating on specific aspects, synthesizing information, identifying patterns, selecting data relevant to the research topic, and formulating conclusions that could be communicated to others. The data were analyzed using an interactive analysis technique. The process consisted of four stages: data collection, data reduction, data presentation, and conclusion drawing and verification, resulting in a coherent synthesis of the research findings (Creswell & Creswell, 2017).

Results and Discussion

1. The Concept of Mathematics Learning According to Zoltan P. Dienes' Theory
   a. Definition of Mathematics Learning in Elementary Schools

      Mathematics is a subject taught at all levels of education, from elementary school to higher education. The learning approach discussed here was first developed and implemented in the Netherlands, where it successfully helped students learn mathematics more easily. However, mathematics learning in schools is not always perceived as an enjoyable activity. In everyday life, many human activities are closely related to mathematics. Therefore, mathematics instruction should emphasize the connections between mathematical concepts and students' daily experiences. It is also important to encourage students to apply the mathematical concepts they have acquired to everyday situations and other related fields (Sohilait, 2021b). Furthermore, mathematics serves as a tool for human activities and supports other scientific disciplines for both theoretical and practical purposes. Its practical value is evident in everyday activities, such as counting, addition, subtraction, multiplication, and division. One application of mathematics is understanding numbers as a foundation for learning measurement (Sholeh & Fahrurozi, 2021).

      The fundamental objectives of mathematics education in elementary and secondary schools comprise two main aspects. First, students should be prepared to face changes in an ever-evolving world by developing the ability to think and act logically, rationally, critically, carefully, honestly, effectively, and efficiently. Second, students should be equipped to use mathematics and mathematical reasoning in everyday life and in learning other disciplines. However, various factors can contribute to students' difficulties in learning mathematics, including low interest and motivation. Inappropriate instructional approaches can also make mathematical concepts more difficult for students to understand (Hendriani, 2021).

      Therefore, teachers need to prepare thoroughly before delivering mathematics lessons. Teachers play a crucial role in determining whether educational objectives are achieved because they interact directly with students and provide the guidance needed to develop the expected competencies. Inadequate lesson preparation can significantly affect the learning process and students' learning outcomes. Lesson preparation serves as a guide for teachers to ensure that instruction is systematic, effective, and efficient.

This preparation includes selecting appropriate teaching materials, considering students' levels of cognitive development, determining suitable timing for presenting the content, choosing appropriate teaching methods, and identifying other resources that support the learning process and help achieve the intended instructional objectives (Anggraini, 2021b).

b. The Learning Theory of Zoltan P. Dienes

Research on Zoltan P. Dienes' theory indicates that some students enjoy mathematics only during the initial stages of learning. When students are introduced to simple mathematical concepts and successfully solve problems, they may feel proud of their achievements, even when those achievements involve relatively basic mathematical concepts (Muna, t.t.). According to Dienes, mathematical concepts can be mastered more easily through play because students become more enthusiastic about the learning materials presented to them (Legi, 2021). Dienes also argued that mathematical concepts are more readily understood when presented in concrete forms (Janapria, n.d.).

Furthermore, Dienes identified six stages of learning through play:

1) Free Play: At this stage, students explore and engage in activities without structured rules or specific directions.
2) Games: Students investigate patterns and regularities associated with particular mathematical concepts through activities governed by rules.
3) Searching for Commonalities: Students identify shared properties among the games or activities in which they participate.
4) Representation: Students summarize and represent the common properties identified across different situations.
5) Symbolization: Students express their representations using mathematical symbols or verbal formulations.
6) Formalization: Students organize the properties of a concept systematically and formulate new properties based on their understanding (Janapria, n.d.).

c. The Importance of Applying Dienes' Theory in Mathematics Learning

According to Susanto, elementary school children are generally at the concrete operational stage of cognitive development. At this stage, they begin to think logically about tangible objects but still require direct experiences to understand abstract concepts (Gusmarlia, 2025). Therefore, instructional media play an important role in teaching and learning because they can increase student engagement, clarify abstract concepts, and enhance learning motivation (Satriana dkk., 2025b)

One type of instructional media that can be used is concrete learning media, consisting of real objects or materials that help students understand mathematical concepts through direct experience (Purbarani, 2024). In the context of twenty-first-century mathematics education, integrating the theories of John Dewey, William A. Brownell, and Zoltán P. Dienes has become increasingly relevant, given the growing emphasis on meaningful, contextual, and reflective learning experiences (Alivah dkk., 2025a).

2. Stages of Mathematics Learning According to Zoltan P. Dienes

a. Stages of Mathematics Learning According to Dienes

1) Free Play

At this stage, students are given opportunities to explore concrete objects freely, such as blocks, number cards, or objects from their surroundings. The aim is to help students feel comfortable with mathematics and become familiar with the objects they will study through natural exploration.

2) Games with Rules

Once students become familiar with these objects, teachers introduce simple rules through games. Through these activities, students gradually begin to recognize mathematical concepts and patterns, even though they may not yet understand them formally.

3) Searching for Commonalities

At this stage, students observe and compare the different games and activities they have experienced. They begin to identify similarities, patterns, and particular properties of the objects or activities. This process helps students construct their understanding of mathematical concepts independently.

4) Representation

After identifying patterns or concepts, students are asked to express their understanding in different forms, such as pictures, diagrams, tables, or models. This stage helps students connect concrete experiences with visual representations.

5) Symbolization

At this stage, students begin to use mathematical symbols to express the concepts they have understood. For example, they use numbers, operational signs, and other mathematical symbols, allowing their understanding to develop toward more formal mathematical expression.

6) Formalization

The final stage occurs when students develop a more systematic and formal understanding of mathematical concepts. They can explain mathematical rules, properties, or formulas and apply them to solve problems.

b. Characteristics of the Learning Stages

Students' characteristics should not be considered solely as indicators for measuring cognitive abilities. Rather, these characteristics need to be understood, studied, and incorporated effectively into instructional practices (Ayuni et al., 2023). This is particularly important because elementary school students generally share several characteristics: (1) they enjoy playing, (2) they enjoy physical movement, (3) they enjoy working in groups, and (4) they enjoy experiencing, performing, or demonstrating activities directly (Midiyanto & Hunaifi, 2022).

Student diversity includes differences in intelligence and learning styles, while learning readiness is associated with students' developmental stages. These stages include: (1) cognitive development, involving the ability to develop skills, understand learning materials, and solve problems; (2) social development, involving the ability to establish relationships and interact effectively with others; (3) language development**,** involving the ability to understand and pronounce words; and (4) physical development, involving bodily growth and development (Hafifah et al., 2023a).

Therefore, effective mathematics instructional media should have the following characteristics:

1) Concrete: Uses tangible materials that provide direct experiences and help students understand abstract concepts.
2) Visual: Incorporates pictures, diagrams, or videos to help students understand mathematical concepts.
3) Interactive: Enables students to interact directly with mathematics learning materials.
4) Adaptive: Can be adjusted to students' individual needs and abilities.
5) Engaging: Uses games or enjoyable activities to increase students' enthusiasm and motivation.
6) Effective: Captures students' attention, encourages their interest in mathematics, and increases their motivation to learn at the elementary school level .(Mailani et al., 2025).

c. Objectives of the Mathematics Learning Stages According to Dienes

The primary objective of applying Dienes' learning stages is to facilitate students' understanding and improve elementary school students' learning outcomes, particularly in addition and subtraction. Beyond these operations, the approach can also be used to introduce fundamental number concepts, place value, including units, tens, hundreds, and thousands, and basic arithmetic operations (Muin, 2023), In practice, manipulatives such as Dienes blocks, fraction cards, and visual materials have been found to help students understand mathematical structures and relationships progressively. These materials can also build students' confidence in solving mathematical problems, increase active participation, strengthen emotional engagement in learning, encourage cognitive involvement, and minimize conceptual errors. The use of tangible objects supports students' understanding of fundamental mathematical concepts. The Dienes approach can therefore establish a cognitive bridge between concrete experiences and mathematical abstraction while supporting constructivist learning (Alivah dkk., 2025b).

Furthermore, used materials and readily available objects from the surrounding environment can serve as play materials with educational value (Ellen Tinoko, 2022). Natural materials can be used to create various products, such as paintings, hats, and dolls made from leaves. They can also support mathematics activities, including measuring, distinguishing rough and smooth textures, and classifying different shapes. Using natural materials to develop children's mathematical reasoning through activities such as classifying shapes and sizes, measuring, counting, and enumerating can make learning meaningful and enjoyable (Chodijah, 2021).

The use of manipulatives can also develop students' motor skills and facilitate their understanding of place value because these materials contain standardized units, ranging from small single units to longer units representing tens. Consequently, such teaching aids can help students understand and perform addition and subtraction more easily (Hafifah et al., 2023b)

3. Implementing Dienes' Learning Stages in Elementary School Mathematics Education

a. The Use of Mathematics Learning Media and Teaching Aids

Instructional media are components of the classroom environment that support the teaching and learning process and help ensure that learning activities proceed as intended. These media offer several benefits. They can help present learning materials

consistently, make content easier to understand, facilitate more interactive learning, increase students' interest, and be used in different settings and at different times (Lazuarni et al., 2024).

In addition to instructional media, teaching aids are tools specifically designed and developed to support classroom learning. They can transform abstract concepts into concrete forms that students can observe and manipulate directly. In elementary mathematics education, teaching aids are particularly important for helping students understand mathematical concepts, especially three-dimensional geometric shapes. Research has shown that using teaching aids can improve students' learning outcomes compared with instruction that does not use such aids, making the learning process more effective and efficient (Puspitasari et al., 2022).

The benefits of mathematics instructional media in elementary schools are diverse. One important benefit is improving students' understanding of fundamental mathematical concepts, including arithmetic operations, geometry, and measurement, which form the foundation for learning at higher levels. Instructional media can also develop critical thinking and problem-solving skills by providing students with more concrete and practical learning experiences (Eliani & Apriza, 2025). One example is *Game Eleven Pieces Multiplication* (GEPION), a multiplication learning game made from distinctive small wooden pieces. This engaging medium can also be created independently by students at home. Its use is expected to increase students' interest in learning mathematics, particularly multiplication (Hardiansyah & AR, 2022).

b. Game-Based Mathematics Learning

Educational games can generally be classified into two types: online games and traditional games. Online educational games use digital platforms, but they also present challenges. For example, some teachers may lack the technological skills needed to use them effectively or may have difficulty selecting games appropriate for their students (Prestisdiva & Kusuma, 2023). Nevertheless, games have considerable potential to create interactive and enjoyable learning experiences. In education, games serve purposes beyond entertainment; they can effectively develop students' critical thinking skills. Through challenging game mechanics, students learn to analyze information, evaluate alternatives, and solve problems in an engaging and interactive environment (Darwin et al., 2024).

Besides digital games, traditional games can provide an effective alternative for mathematics instruction. One mathematical topic often considered difficult by students is the basic concept of the least common multiple (LCM), which requires an understanding of the multiples of numbers and how to identify the smallest common multiple of two or more numbers. The traditional game of *congklak* can serve as an engaging medium for introducing this concept. Congklak is a traditional game that uses seeds or small counters as playing pieces. Players must count the pieces they collect and determine their next moves according to the rules of the game (Kurnia & Sari, 2023).

Other familiar games and teaching aids, such as snakes and ladders, domino cards, UNO cards, and fishing-card games, can also be incorporated into mathematics instruction. Because students are already familiar with these activities, they can provide

enjoyable learning experiences and increase students' interest and enthusiasm for learning mathematics (Fendiyanto dkk., 2024).

c. The Teacher's Role in Implementing Dienes' Learning Stages

Teachers play an important role in mathematics education by selecting teaching methods that suit the characteristics of the subject matter and students. They are also responsible for managing the classroom to create a supportive learning environment that encourages active student participation (Isnaini et al., 2026). Dienes' theory emphasizes that learning can proceed more smoothly and creatively when teachers give students opportunities to discover rules, theories, concepts, definitions, and other mathematical principles through their own learning experiences (Mahmudah et al., 2022).

Furthermore, successful learning depends substantially on teachers' ability to plan instruction effectively. Teachers are therefore responsible for preparing lesson plans that reflect their understanding of instructional models and methods, the appropriate use of teaching aids and learning media, students' characteristics and needs, and the learning environment and facilities available (Farhana et al., 2022). By fulfilling these responsibilities effectively, teachers can create mathematics learning experiences that are meaningful, effective, and oriented toward achieving the intended learning objectives (Isnaini et al., 2026)

Conclusion

Based on the findings and discussion, it can be concluded that the application of Zoltán P. Dienes' learning theory plays an important role in helping elementary school students understand mathematical concepts more easily and meaningfully. Mathematics learning should not focus solely on calculations or the application of formulas but should also connect mathematical concepts with students' real-life experiences through concrete objects, instructional media, and enjoyable learning activities. This approach aligns with the characteristics of elementary school students, who are generally at the concrete operational stage of cognitive development and can understand concepts more effectively through direct experiences.

Furthermore, Dienes' six learning stages, namely free play, games with rules, searching for commonalities, representation, symbolization, and formalization, can help students develop their understanding of mathematical concepts progressively, moving from concrete experiences toward abstract thinking. Implementing these stages through instructional media, teaching aids, and educational games can enhance students' learning motivation, engagement, and conceptual understanding. Therefore, Dienes' learning theory can serve as an effective and engaging alternative strategy for mathematics instruction that is appropriate to the cognitive development of elementary school students.

Author Contributions

Alfina Aulia Rahman contributed to the conceptualization of the study, formulation of the research objectives, and development of the literature review framework. Amanda Revalina contributed to searching for and collecting literature relevant to Zoltán P. Dienes' learning theory. Asti Muslihah Atikah contributed to article selection, identification of relevant information, and organization of the literature data. Zalfa Ramadhani contributed to the analysis

and synthesis of literature findings based on Dienes' six stages of learning. Mely Nur Safitri contributed to the interpretation of the review findings and discussion of the implications of applying Dienes' theory to elementary school mathematics education. Oktaviana contributed to drafting and editing the manuscript, refining the article structure, and checking consistency among the research objectives, methods, results, and conclusions. All authors contributed to reviewing the final manuscript and approved the version for publication.

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