

# Between Formula Memorization and Conceptual Understanding: A Critique of the Dominance of Procedural Learning in Mathematics Education

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## ABSTRACT

*The dominance of procedural learning in mathematics education raises concerns when mastery of formulas and algorithms is prioritized over understanding the underlying concepts. This study aims to critically analyze the relationship between conceptual and procedural knowledge and examine the impact of the dominance of procedural learning on students' mathematical abilities. This study employs a library research method by reviewing various scholarly sources related to conceptual knowledge, procedural knowledge, procedural fluency, mathematical reasoning, and problem-solving. Relevant literature was identified, selected, compared, and synthesized to determine patterns of findings and develop a critical perspective on mathematics learning. The results of the review indicate that conceptual and procedural knowledge should not be positioned as two opposing forms of knowledge, as they can develop in an interconnected manner. However, procedural learning becomes problematic when students merely memorize formulas and follow algorithms without understanding their mathematical meaning. Such conditions have the potential to limit strategic flexibility, knowledge transfer, reasoning, and problem-solving abilities. Therefore, mathematics learning needs to integrate conceptual understanding with procedural fluency. These findings are important as a basis for developing mathematics instruction and assessment that focus not only on obtaining correct answers but also on understanding and mathematical thinking skills.*

**Keywords:** Conceptual Knowledge, Formula Memorization, Mathematics, Procedural Fluency, Procedural Knowledge

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## INTRODUCTION

Mathematics is often perceived as a discipline associated with numbers, symbols, formulas, and problem-solving procedures. In the context of education, this perception is frequently reflected in classroom practices. Students are introduced to a formula, given examples of how to use it, and then asked to solve a series of problems with similar patterns (AlAyyubi et al., 2025). Learning success is then often identified by students' ability to obtain correct answers within a certain amount of time. Such a learning model can indeed develop procedural skills. Students become proficient in performing operations, applying algorithms, and solving routine problems. However, a fundamental question arises: does the ability to follow procedures demonstrate that students truly understand mathematics? This question is important because mathematics is not merely a collection of rules that must be followed. Mathematical knowledge encompasses the ability to understand concepts, recognize relationships, use representations, select strategies, provide reasoning, assess the reasonableness of answers, and adapt knowledge when encountering different problems (Karsenty, 2020). The National Research Council, through *Adding It Up*, describes mathematical proficiency as an integrated whole consisting of several interconnected components, including conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition. Thus, mastery of procedures is an essential component of mathematical proficiency, but it does not constitute the entirety of such proficiency.

The issue becomes more complex when procedural learning develops into mechanistic learning. In such learning, students may know that a particular problem should be solved using a specific formula but may not understand the mathematical reasoning behind that formula. Students know how to perform a task but are unable to explain why the method is correct, when it should be used, or whether there are alternative approaches that may be more appropriate. For example, a student may memorize the formula for the area of a circle and apply it correctly when the radius is explicitly given. However, this ability alone is insufficient to demonstrate conceptual understanding. Deeper understanding would be evident when students are able to explain why the area is related to the square of the radius, connect the area of a circle with geometric representations, compare solution strategies, or apply the concept in situations that do not explicitly require the use of the circle-area formula. This is where the distinction between “knowing a formula” and “understanding mathematics” becomes evident.

Criticism of procedural learning is not a new idea. The National Council of Teachers of Mathematics (NCTM) emphasizes that procedural fluency should be built upon conceptual understanding. Procedural fluency does not merely mean being able to execute an algorithm but also being able to select and use strategies accurately, efficiently, and flexibly. NCTM further emphasizes that the teaching of concepts and procedures needs to be explicitly connected. However, one aspect requires further critical examination. Criticism of procedural learning sometimes results in an overly simplistic dichotomy in which concepts are regarded as good while procedures are regarded as bad. In reality, research on the relationship between conceptual knowledge and procedural knowledge indicates that the two do not exist as opposing forms of knowledge. Rittle-Johnson, Schneider, and Star, through their review of empirical evidence, demonstrated that the relationship between the two is

bidirectional. Conceptual knowledge can support the development of procedural knowledge, while procedural knowledge can also support the development of conceptual knowledge (Tasni, 2026; Wiryanto et al., 2026).

These findings raise a more interesting question: if procedures can also contribute to the development of conceptual understanding, does the problem actually lie in procedural learning itself, or in the way procedures are taught? This question constitutes the critical point of the present study. Therefore, this study does not seek to eliminate procedures from mathematics learning but rather to critically examine the dominance of proceduralism that separates algorithms from mathematical meaning. This study aims to critically analyze the relationship between conceptual and procedural knowledge in mathematics learning, identify the risks of formula-memorization-oriented learning, analyze the reciprocal relationship between concepts and procedures, and formulate the characteristics of mathematics learning that can effectively integrate both.

## **METHOD**

This study employs a library research or literature review method with a descriptive-critical approach. This method was selected because the study focuses on examining and analyzing various sources of literature discussing the relationship between conceptual knowledge and procedural knowledge in mathematics learning (Haryono et al., 2024). The study does not involve direct data collection through observations, interviews, or experiments; instead, it utilizes secondary data obtained from previous research findings, academic books, scholarly journal articles, research reports, and official documents relevant to the focus of the study. The data sources for this study were obtained through searches of various scholarly literature addressing mathematical conceptual understanding, procedural knowledge, procedural fluency, mathematical reasoning, problem-solving, and understanding-oriented mathematics learning. The literature search was conducted through various academic databases, including Google Scholar, ERIC, ScienceDirect, Springer, Taylor & Francis, as well as relevant national scholarly journals. The keywords used in the search process included conceptual knowledge in mathematics, procedural knowledge in mathematics, conceptual and procedural knowledge, procedural fluency, mathematical understanding, rote learning in mathematics, mathematical reasoning, and mathematics problem solving. To obtain Indonesian-language literature, the search also employed keywords such as “pemahaman konsep matematika,” “pengetahuan prosedural matematika,” “pembelajaran prosedural,” “hafalan rumus matematika,” “penalaran matematis,” and “pemecahan masalah matematika.”

The literature was selected selectively by considering the relevance of each source to the research problem. The literature primarily consisted of academic sources that directly discuss the relationship between conceptual and procedural knowledge in mathematics learning or provide a theoretical foundation for the issue under investigation. Scholarly journal articles, academic books, research reports, and documents from credible professional mathematics education organizations were used as the main sources. Literature that was not directly related to the research focus, lacked an adequate academic foundation, or discussed mathematics solely from a disciplinary perspective without a connection to the learning process was not used as a primary source for the analysis. The data analysis process was conducted

descriptively, comparatively, and critically. At the initial stage, the researchers identified and reviewed the literature obtained to understand the concepts, arguments, and research findings related to conceptual and procedural knowledge. Subsequently, information from various sources was classified according to relevant themes, such as the characteristics of conceptual knowledge, the characteristics of procedural knowledge, the distinction between conceptual understanding and procedural memorization, the relationship between conceptual and procedural knowledge, procedural fluency, and the implications of procedural learning for mathematical reasoning and problem-solving abilities. The findings from various studies were then compared to identify similarities, differences, trends, and debates present in the literature (Assyakurrohim et al., 2022).

The next stage involved conducting a critical synthesis of the findings. At this stage, the researchers did not merely summarize previous research findings but also analyzed the relationships among the findings to obtain a more comprehensive understanding of the role of procedural knowledge in mathematics learning. The analysis was directed toward answering the question of whether procedural learning is inherently problematic in mathematics education or whether the problem arises when procedures are taught mechanically without being connected to conceptual understanding. A critical approach was also employed to avoid a simplistic dichotomy between concepts and procedures, considering that several studies indicate that conceptual and procedural knowledge have a reciprocal relationship. The validity of the information in this study was maintained through the comparison of various relevant literature sources, or source triangulation. Findings from one study were compared with those of other studies to determine the consistency and differences among the results. In this way, the conclusions of the study were not based on a single source or perspective but rather resulted from a synthesis of various studies and academic perspectives. The final results of the analysis were then used to formulate arguments concerning the importance of integrating conceptual understanding and procedural skills in mathematics learning and to provide a critique of learning practices that regard formula memorization and success in solving routine problems as the primary indicators of successful mathematics learning.

## **RESULT AND DISCUSSION**

### **RESULT**

Based on a review of various sources of literature on mathematics learning, conceptual knowledge, procedural knowledge, procedural fluency, mathematical reasoning, and problem-solving, it was found that issues surrounding procedure-oriented mathematics learning cannot be understood simply as a conflict between formula memorization and conceptual understanding (Al Ayyubi et al., 2024). The literature indicates that procedural knowledge and conceptual knowledge are two distinct but closely related and mutually influential components. Procedural knowledge enables students to perform mathematical actions through particular steps or algorithms, whereas conceptual knowledge enables students to understand the relationships, principles, structures, and meanings underlying those actions. The National Research Council places conceptual understanding and procedural fluency as interconnected components of mathematical proficiency, alongside strategic competence, adaptive reasoning, and productive disposition toward mathematics.

Thus, mathematical proficiency cannot be reduced merely to the ability to calculate or follow algorithms.

The findings indicate that procedural learning plays an important role in the development of mathematical abilities. Students still need the ability to perform operations, use algorithms, recognize solution patterns, and execute procedures accurately and efficiently. Procedures help students automate certain skills so that cognitive resources can be allocated to thinking about more complex aspects of a problem. Therefore, the presence of procedures in mathematics learning is not inherently problematic. The problem arises when procedures are learned as isolated rules, detached from the concepts underlying them, and when the ability to execute procedures is regarded as sufficient evidence that students understand mathematics. This condition can be referred to as mechanistic proceduralism, namely a tendency in learning that places algorithms, formulas, and sequences of steps at the center of learning activities, while mathematical reasoning, relationships among concepts, representations, and reasoning processes receive less attention (Allen, 2023; Nilsson, 2020). In mechanistic proceduralism, students tend to be directed to identify the form of a problem, recall the appropriate formula, substitute the given information into the formula, and obtain the final answer. This pattern can produce good results on routine problems because the form of the problem and its solution procedure are relatively predictable. However, such abilities do not necessarily persist when the structure of the problem is changed. Students may know “what to do” when faced with familiar problems but may not always be able to explain “why it is done” or determine an appropriate strategy when encountering a new situation.

These findings indicate a fundamental distinction between the ability to produce an answer and the ability to understand mathematics. A correct answer is an important indicator in mathematics learning, but a correct answer does not always provide sufficient information about the structure of a student's knowledge. Two students may obtain the same answer through different processes. The first student may understand the mathematical principle being used and be able to explain the reasoning behind each step, whereas the second student may simply recall a previously taught solution pattern. If both students are given a problem identical to a previous example, they may both obtain the correct answer. However, when the problem is modified, the student with stronger conceptual understanding is likely to have more resources available to adapt their solution strategy (Krajcik & Shin, 2023; Xu et al., 2025). This difference becomes increasingly apparent in tasks that require knowledge transfer. In mathematics learning, transfer does not merely mean using the same formula with different numbers but rather applying previously learned knowledge to situations with different structures. Students who understand concepts can recognize mathematical relationships even when the surface features of a problem change. Conversely, students who rely too heavily on procedural memorization may experience difficulties because they no longer encounter cues that directly indicate a particular algorithm. Thus, the depth of understanding can be assessed not only through the ability to solve familiar problems but also through the ability to use knowledge flexibly in different situations.

The review also found that the relationship between conceptual and procedural knowledge is bidirectional. Rittle-Johnson, Schneider, and Star reviewed various empirical findings concerning the relationship between the two and demonstrated

that conceptual knowledge can support the development of procedural knowledge, while procedural knowledge can also contribute to the development of conceptual knowledge. These findings challenge the linear view that mathematics learning must always proceed from concepts to procedures. Instead, the relationship between the two is better understood as an iterative process in which conceptual understanding and procedural mastery develop and reinforce each other over time. The findings further indicate that the concept of procedural fluency needs to be distinguished from mere procedural skill. Mechanistic procedural ability enables students to execute particular algorithms, whereas procedural fluency requires the ability to use procedures accurately, efficiently, flexibly, and appropriately according to the situation. NCTM emphasizes that procedural fluency should be built upon conceptual understanding and that students should have opportunities to learn more than one strategy. The ability to select an appropriate strategy and switch strategies when the initial method is ineffective is an essential component of genuine procedural fluency.

The review also demonstrates that learning that emphasizes only a single algorithm can limit students' mathematical flexibility. When students are consistently given one method that is regarded as the “correct” approach, they may develop the belief that every mathematical problem has one procedure that must be identified and followed. In reality, mathematics often allows for the use of multiple representations and strategies. In certain contexts, a more intuitive or simpler strategy may lead to the same solution as a formal algorithm. NCTM emphasizes the importance of providing students with opportunities to use more than one method so that they can select an approach appropriate to the characteristics of the problem (Jahangiri et al., 2022). This phenomenon has implications for problem-solving abilities. Routine problems generally provide sufficiently clear structures that allow students to identify the required procedure. In contrast, non-routine problems require students to understand the situation, determine relevant information, construct representations, select strategies, reason, and evaluate their results. Students who are accustomed to learning through the pattern of “problem, formula, substitution, answer” may experience difficulties when such relationships are not explicitly provided. Thus, procedural dominance has the potential to limit the development of strategic competence when procedures are not accompanied by opportunities to analyze and select strategies.

The findings also indicate that issues surrounding procedural learning are related to how mathematical abilities are assessed. When assessments place greater emphasis on final answers and speed, students may receive the message that mathematics is primarily about producing answers quickly. Under such conditions, memorizing formulas and algorithms becomes a rational strategy for students because it aligns with the demands of the assessment. NCTM emphasizes that the assessment of fluency should not focus solely on accuracy but should also consider efficiency and flexibility. Furthermore, timed tests do not automatically measure procedural fluency (Andika, 2025; Hidajat, 2024; Kurniawan, 2020). Overall, the findings indicate that the issue requiring attention is not the existence of procedural learning itself but rather the imbalance between procedures and understanding. Procedural learning becomes problematic when students are not given opportunities to understand the meaning of procedures, connect them to concepts, compare them with alternative strategies, and apply them to different situations. Conversely, learning that integrates concepts and procedures enables students to benefit from both. Procedures provide efficiency and

accuracy, while conceptual understanding provides a foundation for selecting, explaining, modifying, and transferring procedures. The synthesis of the literature indicates that conceptual and procedural knowledge have a complementary relationship in mathematics learning. Procedures contribute to accuracy and efficiency, while conceptual understanding supports the flexible use of procedures. A summary of these findings is presented in Table 1.

**Table 1.** Synthesis of Literature Findings on Conceptual and Procedural Learning

| <b>Dimensions Examined</b>     | <b>Patterns Identified in the Literature</b>                                                                                                           | <b>Implications for Mathematics Learning</b>                                                  |
|--------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| Concept-procedure relationship | The relationship between the two is reciprocal rather than one-directional                                                                             | Learning does not need to position concepts and procedures as two completely separate stages. |
| Use of algorithms              | Algorithms are effective for producing accurate and efficient solutions, but their effectiveness depends on adequate understanding and appropriate use | Algorithms need to be positioned as part of the mathematical thinking process                 |
| Strategic flexibility          | Mastery of a single procedure does not necessarily demonstrate the ability to select an appropriate strategy                                           | Students need opportunities to use and compare multiple strategies                            |
| Knowledge transfer             | Using procedures on familiar problems does not automatically demonstrate the ability to apply them to different situations                             | Learning should provide a variety of problems and contexts                                    |
| Mathematical errors            | Errors do not always result from an inability to carry out steps; they may also be related to the selection or interpretation of procedures            | Error analysis should consider students' thinking processes, not merely their final answers   |
| Procedural fluency             | <i>Procedural fluency</i> includes accuracy, efficiency, and flexibility                                                                               | Speed in solving problems should not be used as the sole indicator of procedural fluency      |
| Assessment                     | Assessment that focuses only on accuracy tends to overlook flexibility and mathematical reasoning                                                      | Assessment should provide opportunities for explanations, strategies, and decision-making     |

| Dimensions Examined   | Patterns Identified in the Literature                                                            | Implications for Mathematics Learning                           |
|-----------------------|--------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|
| Role of understanding | Conceptual understanding serves as a foundation for using procedures meaningfully and adaptively | Understanding should be developed alongside procedural practice |

Table 1 shows that the main issue does not lie in the use of procedures themselves, but rather in the use of procedures without adequate understanding. Mastery of algorithms needs to develop into the ability to select appropriate strategies, apply procedures in different situations, and explain the mathematical reasoning underlying a solution. These findings indicate that mathematics learning needs to integrate conceptual and procedural knowledge so that students are not only able to obtain correct answers but also able to use their knowledge flexibly.

## DISCUSSION

The findings of this study lead to a fundamental question concerning what is actually meant by “learning mathematics.” In educational practice, mathematics is often reduced to the activity of obtaining correct answers through certain procedures. This reduction is understandable because mathematics does require symbolic and procedural accuracy. However, when the final answer becomes the sole indicator of success, important aspects of mathematical activity, such as understanding relationships, formulating conjectures, providing reasoning, using representations, selecting strategies, and evaluating the reasonableness of results, may be overlooked. The National Research Council views mathematical proficiency as a construct consisting of several interconnected components rather than merely procedural skills (Kurniati et al., 2025). From this perspective, formula memorization is not the enemy of mathematics learning. Memorization can be part of learning when it is used to support fluency. For example, a student who has automatically mastered basic facts can allocate greater attention to solving more complex problems. The problem arises when memorization does not develop into meaningful knowledge. Memorization becomes problematic when students know the form of a formula but do not understand the mathematical relationship it represents, do not know the conditions under which it should be used, and are unable to determine whether the result obtained is reasonable.

The distinction between memorization and understanding can be illustrated through the example of a linear equation. When students solve  $(2x + 6 = 14)$ , they may use the rule commonly referred to as “moving terms across the equal sign” to obtain  $(x = 4)$ . Procedurally, this method produces the correct answer. However, there is a conceptual difference between a student who understands that 6 must be subtracted from both sides to preserve equality and a student who merely remembers that a positive number “changes” to a negative number when it is “moved” to the other side. In a simple problem, both students may provide the same answer. However, when the form of the equation changes, an understanding of equality provides a stronger basis for determining the next step. This example shows that the problem with memorization does not primarily lie in the act of remembering, but in what is actually

represented by what has been remembered. The same issue can be found in geometry. Students may memorize the formula for the area of a triangle and then substitute the values of the base and height when the information is explicitly provided. However, conceptual understanding requires students to recognize the relationship between the area of a triangle and the area of a rectangle or parallelogram, understand why the factor  $\frac{1}{2}$  appears, and know how the concept can be applied when the position of the triangle changes. When students understand the origin and relationships underlying a formula, the formula is no longer an isolated object of memorization but rather a concise representation of an already-understood geometric relationship.

From this perspective, procedural learning should not be eliminated but reconstructed. Procedures need to be positioned as part of a network of mathematical knowledge. When students learn an algorithm, they need opportunities to understand the purpose of the algorithm, the reasoning behind each step, the conditions under which the algorithm can be used, and its relationship to other representations. In this way, students do not merely acquire a “recipe” for solving problems but understand the structure that enables the recipe to work. This argument is supported by the NCTM's view that *procedural fluency* should be built upon conceptual understanding. In its official documents, NCTM emphasizes that the learning of procedures and concepts should be explicitly connected and that learning algorithms through memorization alone is insufficient for developing strong mathematical competence. NCTM also emphasizes that students need a repertoire of strategies and opportunities to select strategies that are appropriate to the problem (Crosswhite et al., 1989; Jahangiri et al., 2022; Koestler, Courtney; Felton-Koestler, Mathew; Bieda, Kristen; Otten, 2013).

However, an important correction is needed regarding extreme views of conceptual understanding. It is not appropriate to argue that concepts must always be fully learned before procedures are introduced. Empirical evidence indicates a more complex relationship. Rittle-Johnson, Schneider, and Star demonstrate that the relationship between conceptual and procedural knowledge is bidirectional. Procedures can help students develop or strengthen conceptual understanding, while conceptual understanding can make the use of procedures more meaningful and flexible. These findings change the way we understand the sequence of learning. Rather than viewing learning as a linear process moving from concepts to procedures, learning can be understood as a cyclical process. Students develop an initial understanding of a concept, use a particular procedure, identify patterns through the use of the procedure, reinterpret those patterns conceptually, and then use their new understanding to select or modify procedures. This process may occur repeatedly at increasingly complex levels.

For example, in learning fractions, students may first understand fractions through part-whole representations. They then learn procedures for adding fractions. When using these procedures, students may discover that fractions with different denominators require a particular approach to create comparable units. Understanding this process can then strengthen their concept of equivalent fractions. At the next stage, this understanding can help students recognize why a particular procedure is necessary when denominators differ. In this example, concepts and procedures do not operate separately but rather reinforce one another. This

perspective also explains why the term *procedural fluency* is more appropriate than simply “procedural ability.” Procedural fluency is not merely the ability to execute an algorithm automatically. The National Research Council defines *procedural fluency* as the ability to carry out procedures flexibly, accurately, efficiently, and appropriately, while mathematical proficiency also requires the ability to formulate and solve problems and engage in adaptive reasoning. Thus, a person can be considered procedurally fluent when they are not only able to execute a procedure but also understand when it should be used and why it is appropriate.

This becomes particularly important in problem-solving instruction. When students merely memorize algorithms, they tend to look for surface similarities between the problem they are facing and examples they have previously studied (Prameswari et al., 2026). This strategy is effective when the surface structure and mathematical structure of the problems are relatively similar. However, in non-routine problems, surface similarities can be misleading. Students need to be able to identify deeper structures. Conceptual understanding helps students make such identifications because they do not rely solely on the appearance of a problem but understand the underlying mathematical relationships. For example, students who learn quadratic equations procedurally may immediately identify the values of (a), (b), and (c) and substitute them into the quadratic formula. This strategy can work for many problems. However, students who understand the structure of quadratic equations have a wider range of options. They can consider factoring, completing the square, using graphs, or applying the quadratic formula depending on the characteristics of the problem. The ability to select an appropriate method represents a higher level of mathematical flexibility than merely being able to recall a formula.

Thus, conceptual understanding should not be viewed merely as theoretical knowledge without practical value. On the contrary, conceptual understanding provides a foundation for using procedures adaptively. When students understand mathematical relationships, they can determine whether a procedure is relevant, estimate the form of the expected answer, and detect unreasonable results. NCTM emphasizes that when students use procedures they do not understand, they are more vulnerable to errors and less able to recognize when the results they obtain are unreasonable. This issue leads to a discussion of mathematical errors. In mechanistic procedural learning, errors are often viewed simply as mistakes in a particular step that need to be corrected immediately. Such an approach may overlook information about the structure of students' thinking. Errors can actually indicate whether students lack conceptual understanding, have selected an inappropriate procedure, have incorrectly applied a procedure, or possess an inaccurate representation. Therefore, error analysis should not stop at identifying an incorrect answer but should also reveal the reasoning that produced the answer.

For example, if a student incorrectly adds two fractions by adding the numerators and denominators separately, the error is not merely a computational mistake. It may indicate that the student is applying a procedure for adding integers to fractions without understanding that the numerator and denominator of a fraction represent a relationship that cannot be treated independently. If the teacher simply provides the correct answer, the student may know the correction but may not necessarily understand the source of the error. A more conceptual approach would use the error to develop an understanding of equivalent fractions and the need for a

common denominator. The next issue concerns mathematical representations. Learning that is overly procedural tends to prioritize symbolic representation because symbols are regarded as the primary form of school mathematics (Prameswari et al., 2026). However, mathematical understanding can be developed through connections among symbolic, visual, verbal, tabular, graphical, and contextual representations. When students are able to move from one representation to another, they have more opportunities to understand mathematical structures. Representations can also serve as a bridge between concepts and procedures because students can see how an algorithm relates to more concrete mathematical meaning.

Another issue that needs to be considered is the culture of speed in mathematics learning. In many learning experiences, students often receive the message that students who calculate quickly are good at mathematics. This perception can reinforce a procedural orientation because speed is more easily achieved through memorization and automation. However, deep mathematical competence often requires time to explore, make mistakes, consider strategies, and examine reasoning. NCTM explicitly distinguishes *fluency* from mere speed and states that timed tests are not an adequate measure of procedural fluency (Jahangiri et al., 2022). If a culture of speed becomes too dominant, there is a risk that students will develop the perception that mathematical thinking means finding an answer as quickly as possible. Consequently, students may avoid strategies that require exploration and instead prefer familiar procedures. In the long term, this pattern may hinder the development of a productive disposition toward mathematics because students may view difficulty or the need to think for a longer period as evidence that they are “not good at mathematics.”

In this context, assessment plays an important role. If teachers want to develop conceptual understanding but all assessments merely ask students to select formulas and produce answers, there is a mismatch between learning objectives and the assessment system. Assessment should provide opportunities to evaluate thinking processes, reasoning, representations, strategies, flexibility, and the ability to evaluate results. Questions such as “Why is this method correct?”, “Explain using a diagram,” “Use another method,” “Identify the error in the following solution,” or “Explain whether this answer is reasonable” can provide richer information about the structure of students' understanding. Thus, criticism of the dominance of procedural learning is also a critique of how mathematical success is defined. If success is defined solely as the ability to obtain correct answers, proceduralism will continue to dominate because it is a relatively efficient way to produce answers. However, if mathematical success is defined as the ability to understand, use, explain, reason with, and transfer knowledge, then concepts and procedures must be positioned in a more balanced relationship.

From the overall discussion, it can be formulated that ideal mathematics learning is not learning that chooses between concepts and procedures. A more appropriate model is learning that creates conceptual-procedural interaction. At the initial stage, students gain experiences that help them construct meaning. Subsequently, students are introduced to procedures that can be used to solve problems efficiently. These procedures are then applied in various situations so that students can identify patterns, compare strategies, and strengthen their conceptual understanding. Next, students are given opportunities to explain, evaluate, and transfer procedures to new problems. In this way, the learning process forms a cycle

of understanding, doing, reflecting, and applying. Thus, the findings of this study offer a more moderate yet critical position. The problem is not that students memorize formulas, but that memorization often remains merely memorization (Verschaffel et al., 2020). The problem is not that students use procedures, but that procedures are sometimes used without understanding. The problem is not that students need to calculate quickly, but rather that speed is sometimes regarded as the primary representation of mathematical competence. Mathematics learning needs to move beyond merely “knowing how” toward the ability to “know how, know why, know when, and know whether the method makes sense.”

Ultimately, criticism of the dominance of procedural learning is not a call to eliminate formulas, algorithms, or practice. Rather, it is an effort to reposition procedures from being the ultimate goal to becoming tools for developing mathematical competence. Understood procedures can serve as instruments for thinking, whereas procedures that are merely memorized can become mechanical rules that easily break down when the context changes. Therefore, the challenge of mathematics education is not to choose between memorization and understanding but to create learning conditions in which necessary memorization develops into fluency, fluency develops into flexibility, and procedures always maintain clear connections with concepts and mathematical reasoning. This perspective is consistent with NCTM's recommendations, which position conceptual understanding as a foundation for the development of *procedural fluency* while recognizing that both need to be developed in an interconnected and sustained manner.

## CONCLUSION

Based on the results of the literature review, it can be concluded that the dominance of procedural learning in mathematics education is not merely caused by the use of formulas, algorithms, or procedural exercises, but primarily by the tendency to make procedures the ultimate goal of learning without connecting them to conceptual understanding. Procedural knowledge continues to play an important role in mathematics learning because it supports accuracy and efficiency in solving problems. However, mastery of procedures based solely on memorization tends to provide a weak foundation for students to explain mathematical reasoning, select appropriate strategies, deal with variations in problems, and apply their knowledge to new situations. The synthesis of the literature also shows that conceptual and procedural knowledge should not be positioned as two opposing elements. They have a dynamic relationship and can develop reciprocally. Conceptual understanding can help students use procedures accurately and flexibly, while the use of procedures can strengthen their understanding of mathematical patterns and relationships. Therefore, effective mathematics learning is not learning that eliminates procedures in favor of concepts, but rather learning that meaningfully integrates both.

Accordingly, criticism of procedural learning should be directed toward mechanistic proceduralism, namely an approach that emphasizes formula memorization, repetitive algorithmic practice, speed in obtaining answers, and success on routine problems as the primary indicators of mathematical ability. Such an approach has the potential to limit the development of strategic flexibility, knowledge transfer, reasoning, and problem-solving skills when it is not accompanied by adequate conceptual understanding. In contrast, procedural mastery that develops into

*procedural fluency* enables students to use procedures accurately, efficiently, and flexibly according to the characteristics of a given problem. Ultimately, this study emphasizes that the success of mathematics learning cannot be adequately measured solely by students' ability to memorize formulas or obtain correct answers. More comprehensive mathematical competence includes the ability to understand concepts, use procedures, select strategies, provide reasoning, evaluate results, and transfer knowledge to new situations. Therefore, mathematics instruction and assessment should provide a balanced space for conceptual understanding and procedural fluency. Through this shift, formulas and procedures are no longer positioned as the ultimate goals of learning, but rather as tools that help students develop deeper mathematical understanding and competence.

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