

Assessment for Critical Thinking in Mathematics Education: Exploring Classroom Practices and Student Learning

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Abstract:

Critical thinking is an essential component of mathematics education because students need to interpret information, analyze problems, evaluate strategies, justify solutions, and reflect on their mathematical reasoning. However, classroom assessment often remains focused on correct answers and procedural performance, providing limited opportunities to reveal students' higher-order thinking processes. This study explores how assessment practices for critical thinking are implemented in mathematics classrooms and how these practices contribute to students' mathematical learning. A qualitative case study approach was employed, with data collected through classroom observations, semi-structured interviews, and analysis of instructional and assessment documents. The data were analyzed thematically to identify patterns in assessment practices and their relationship with students' critical thinking and learning. The findings indicate that open-ended and non-routine tasks, probing questions, explanation and justification, error analysis, comparison of solution strategies, classroom discussion, formative feedback, and metacognitive reflection provide meaningful opportunities for students to engage in critical thinking. These practices help students analyze mathematical information, evaluate alternative strategies, justify claims, identify and correct errors, and reflect on their problem-solving processes. The study concludes that assessment for critical thinking is most effective when integrated continuously into classroom instruction rather than treated solely as a measurement of learning outcomes. The findings highlight the importance of teacher assessment literacy and the design of assessment practices that make students' mathematical reasoning visible and support meaningful learning.

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Introduction (مقدمة)

Mathematics education plays a fundamental role in developing students' ability to reason, analyze relationships, solve problems, and make logically justified decisions. Mathematics

learning is therefore not limited to the acquisition of formulas, procedures, and computational skills but also involves the development of higher-order cognitive abilities. Among these abilities, critical thinking is particularly important because students are expected to examine information, identify assumptions, evaluate arguments, construct logical explanations, and determine appropriate solutions to mathematical problems. In this context, mathematics classrooms need to provide learning and assessment experiences that allow students to demonstrate how they think, rather than merely whether they can obtain the correct answer (NCTM, 2000; Ennis, 2011).

The importance of critical thinking has become increasingly evident as students encounter complex problems that cannot always be solved through direct application of previously memorized procedures. Mathematical problems may require learners to interpret information, identify relevant variables, compare alternative strategies, recognize patterns, evaluate the validity of a solution, and communicate mathematical reasoning. Such processes require students to move beyond procedural fluency toward conceptual understanding and reflective reasoning. Consequently, mathematics education should provide opportunities for students to explain and justify their thinking, because the ability to provide a mathematically sound justification is an essential component of higher-level mathematical competence (Schoenfeld, 1985; Kilpatrick et al., 2001).

Despite this expectation, classroom assessment in mathematics has often emphasized students' ability to produce correct answers within predetermined procedures. Conventional tests can efficiently measure computational knowledge and procedural proficiency, but they may provide limited information about the reasoning processes students use to reach their answers. When assessment primarily rewards speed, accuracy, and reproduction of established procedures, students may have fewer opportunities to demonstrate interpretation, evaluation, argumentation, and mathematical justification. This creates an important pedagogical concern because what teachers assess can influence what students perceive as valuable to learn and how they approach mathematical tasks (Black & Wiliam, 1998; Shepard, 2000).

Assessment should therefore be understood not merely as a mechanism for measuring learning outcomes but also as an integral component of the learning process. Assessment for learning emphasizes the use of evidence about students' understanding to inform subsequent teaching and learning activities. Through formative assessment, teachers can identify misconceptions, examine students' reasoning, provide feedback, and modify instruction according to students' learning needs. In mathematics education, this approach creates opportunities to use students' responses not simply to assign scores but to understand how they construct mathematical meaning and how their reasoning can be further developed (Black & Wiliam, 1998; Wiliam, 2011).

Assessment for critical thinking requires a shift from asking whether an answer is correct toward examining how and why students arrive at that answer. Tasks designed to assess critical thinking can ask students to explain their reasoning, compare different solution strategies, identify errors, evaluate mathematical claims, construct counterexamples, or justify the validity of a particular conclusion. Such assessment tasks provide richer evidence of students' cognitive processes than questions that require only a numerical response. They also enable teachers to observe dimensions of mathematical thinking that are often invisible in conventional answer-oriented assessments (Ennis, 2011; Brookhart, 2010).

The relationship between assessment and mathematical reasoning is particularly significant because mathematical competence involves interconnected dimensions of conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition. Students who possess mathematical understanding should be able to explain why a procedure works, determine when a particular strategy is appropriate, and evaluate whether a solution is reasonable. Assessment practices that capture these dimensions can provide a more comprehensive picture of student learning and encourage students to treat mathematics as a discipline of reasoning rather than a collection of formulas and algorithms (Kilpatrick et al., 2001).

One promising direction is the use of open-ended and non-routine mathematical tasks. Unlike routine exercises that generally have a familiar solution pathway, open-ended problems may permit multiple strategies, multiple representations, or different forms of justification. These characteristics require students to make decisions about how a problem should be approached and to evaluate the effectiveness of their chosen strategy. When teachers use such tasks as part of assessment, students have greater opportunities to articulate their mathematical thinking, examine alternative solutions, and engage in reflective judgment. Consequently, assessment can function simultaneously as a means of measuring and developing critical mathematical thinking (NCTM, 2000; Sullivan, 2011).

Classroom interaction is also an important element in assessment for critical thinking. Students' mathematical reasoning becomes more visible when teachers ask probing questions, request explanations, challenge assumptions, and invite students to compare different approaches. Formative assessment can therefore occur through classroom dialogue, peer discussion, written explanations, observation, questioning, and feedback, rather than being restricted to formal examinations. Such practices enable teachers to gather ongoing evidence of students' thinking and provide feedback that supports the development of more sophisticated reasoning processes (Heritage, 2010; Wiliam, 2011).

Feedback is another critical component of assessment practices intended to promote critical thinking. Effective feedback should provide students with information that helps them understand the quality of their reasoning and identify possible ways to improve their mathematical thinking. Feedback that simply indicates whether an answer is right or wrong may have limited value for developing higher-order thinking. In contrast, feedback that focuses on reasoning, evidence, strategy selection, explanation, and justification can encourage students to reflect on their cognitive processes and revise their approaches. Assessment thus becomes a dialogic process through which students progressively develop greater responsibility for evaluating their own mathematical thinking (Hattie & Timperley, 2007; Nicol & Macfarlane-Dick, 2006).

However, implementing assessment for critical thinking in mathematics education is not without challenges. Teachers may face difficulties in designing appropriate tasks, developing assessment criteria, interpreting complex student responses, managing classroom time, and providing meaningful feedback to diverse learners. Assessment of reasoning can also be more demanding than scoring conventional mathematical exercises because students may demonstrate different but mathematically valid solution strategies. These challenges indicate that transforming assessment practices requires not only changes in assessment instruments but also teachers' assessment literacy, pedagogical knowledge, and capacity to interpret evidence of student thinking (Brookhart, 2010; Heritage, 2010).

Although considerable scholarship has discussed critical thinking, formative assessment, mathematical reasoning, and assessment for learning, there remains a need to examine how these ideas are enacted in actual mathematics classrooms. Much of the discussion surrounding assessment tends to emphasize assessment models, instruments, or learning outcomes, while less attention may be given to the classroom processes through which teachers use assessment evidence to stimulate students' reasoning and critical reflection. Understanding these practices is important because the effectiveness of assessment for critical thinking depends not only on the type of assessment task but also on how teachers introduce tasks, respond to student thinking, facilitate discussion, and provide feedback during the learning process.

Based on this context, the present study explores classroom assessment practices designed to support critical thinking in mathematics education and examines how these practices contribute to student learning. Rather than treating assessment solely as a measurement of achievement, this study conceptualizes assessment as a pedagogical process through which teachers elicit, interpret, and respond to evidence of students' mathematical thinking. The study focuses on how assessment practices create opportunities for students to analyze mathematical

problems, evaluate strategies, justify solutions, communicate reasoning, and reflect on their learning. Accordingly, the research addresses the following question: How are assessment practices for critical thinking implemented in mathematics classrooms, and how do these practices contribute to students' mathematical learning?.

Method (منهج)

This study employed a qualitative case study design to explore how assessment practices for critical thinking are implemented in mathematics classrooms and how these practices contribute to students' mathematical learning. A qualitative approach was considered appropriate because the study focused on understanding classroom processes, teacher practices, student responses, and the meanings associated with assessment activities rather than measuring the effectiveness of a particular assessment intervention. The case study design enabled the researchers to examine assessment practices within their natural classroom context and to develop an in-depth understanding of how assessment and learning interact during mathematics instruction (Creswell & Poth, 2018; Yin, 2018).

The research was conducted in a mathematics education setting in which classroom assessment was integrated into regular teaching and learning activities. The research setting was purposively selected because it provided opportunities to observe various forms of assessment, including questioning, mathematical tasks, classroom discussions, written work, feedback, and evaluation of students' reasoning. The selection of the setting was intended to provide rich information about how teachers use assessment not only to measure mathematical achievement but also to identify and develop students' critical thinking.

Participants were selected using purposive sampling. The participants consisted of mathematics teachers and students who were directly involved in the observed learning activities and assessment processes. Teachers were selected based on their involvement in planning and implementing mathematics assessment, while students were selected because they participated directly in classroom tasks and assessment activities. Purposive selection allowed the researchers to obtain information from participants who could provide relevant and detailed accounts of assessment practices and students' learning experiences (Patton, 2015).

Data were collected through three complementary techniques: classroom observation, semi-structured interviews, and document analysis. Classroom observations were conducted to examine how teachers designed and implemented assessment activities, how students responded to mathematical tasks, and how classroom interactions revealed students' reasoning. Semi-structured interviews were conducted with teachers and selected students to obtain deeper information about their perceptions, experiences, difficulties, and interpretations of assessment practices. Documents such as lesson plans, assessment instruments, student worksheets, learning materials, and students' written responses were also examined to complement the observational and interview data (Merriam & Tisdell, 2016).

The classroom observation focused on several dimensions of assessment for critical thinking. These included the use of open-ended and non-routine mathematical problems, teacher questioning, opportunities for students to explain and justify their answers, comparison of alternative solution strategies, identification and correction of errors, classroom discussion, peer interaction, and feedback. Particular attention was given to situations in which students were required to analyze information, evaluate mathematical claims, provide evidence, make logical judgments, and reflect on their solution processes. These dimensions were used as analytical indicators rather than as rigid categories, allowing the researchers to remain attentive to unexpected patterns emerging from the classroom context.

The semi-structured interviews explored how teachers understood and implemented assessment for critical thinking and how students experienced the assessment activities. Teacher interviews addressed assessment planning, task selection, questioning strategies, interpretation of student responses, feedback practices, and challenges in assessing mathematical reasoning. Student interviews focused on their experiences in solving mathematical tasks, explaining their reasoning, receiving feedback, comparing different solutions, and reflecting on their learning. The flexible nature of semi-structured interviews allowed participants to elaborate on experiences that were not fully observable during classroom activities (Creswell & Poth, 2018).

Document analysis was used to examine the relationship between planned assessment and actual classroom implementation. Assessment instruments and instructional documents were analyzed to identify the extent to which assessment tasks required students to demonstrate reasoning, problem solving, evaluation, explanation, and justification. Students' written work was examined to identify evidence of mathematical thinking and the ways in which students communicated their solution processes. Comparing planned assessment materials with classroom observations and student work helped the researchers identify consistencies and differences between intended and enacted assessment practices.

The collected data were analyzed using thematic analysis. The analysis involved several stages, beginning with familiarization with the observation notes, interview transcripts, and relevant documents. The researchers then generated initial codes representing important features of assessment practices and student learning. Related codes were subsequently grouped into broader categories, which were reviewed and developed into themes. The analysis followed an iterative process in which emerging themes were continuously compared with the original data to ensure that interpretations remained grounded in participants' accounts and classroom observations (Braun & Clarke, 2006, 2021).

The analysis focused particularly on the relationship between assessment practices and critical thinking in mathematics. Assessment practices were examined in relation to students' abilities to analyze mathematical information, interpret problems, evaluate strategies, justify solutions, communicate mathematical reasoning, and reflect on errors or alternative approaches. The analysis also considered how formative feedback and classroom interaction supported or constrained these processes. The concept of assessment for learning was used to interpret how teachers employed evidence of student understanding to adjust instruction and support subsequent learning (Black & Wiliam, 1998; Wiliam, 2011).

To establish the trustworthiness of the findings, the study employed data triangulation, member checking, and systematic documentation of the research process. Information obtained from classroom observations, interviews, and documents was compared to identify convergent and divergent evidence. Relevant interpretations were also discussed with participants to clarify the meaning of their statements and classroom practices. An audit trail was maintained throughout the research process to document decisions concerning data collection, coding, categorization, and interpretation. These procedures were intended to strengthen the credibility, dependability, and confirmability of the findings (Lincoln & Guba, 1985). Ethical principles were maintained throughout the study by obtaining informed consent, ensuring voluntary participation, protecting participants' identities, and using the collected information exclusively for research purposes.

Result (نتائج)

The findings indicate that assessment in the observed mathematics classrooms functioned not only as a mechanism for measuring students' achievement but also as an integral part of the

learning process. Rather than relying exclusively on end-of-unit examinations, teachers incorporated assessment into classroom activities through questioning, mathematical tasks, observation, discussion, written work, and feedback. This practice created opportunities for teachers to obtain ongoing evidence of students' understanding and to identify how students approached mathematical problems. The findings suggest that assessment became more closely connected to learning when teachers used students' responses as a basis for further explanation, questioning, and instructional adjustment.

One of the prominent findings was the use of open-ended and non-routine mathematical tasks to stimulate students' critical thinking. Students were presented with problems that could be approached through different strategies or required them to explain how they arrived at a particular solution. Such tasks shifted classroom attention from simply obtaining the correct numerical answer toward understanding the reasoning behind the solution. Students were encouraged to identify relevant information, determine appropriate strategies, and explain the mathematical relationships involved in solving a problem. This practice provided teachers with richer evidence of students' mathematical thinking than conventional questions with predetermined solution procedures.

The findings also revealed the important role of teacher questioning in eliciting students' mathematical reasoning. Teachers did not always immediately confirm whether a student's answer was correct. Instead, they frequently used follow-up questions that encouraged students to clarify their reasoning, explain the steps they had taken, or reconsider particular aspects of their solutions. Questions concerning why a strategy was selected, how a conclusion was obtained, or whether another approach could produce the same result encouraged students to move beyond answer production. Through this interaction, assessment became a process of eliciting and examining students' thinking.

Another important finding concerned students' ability to explain and justify mathematical solutions. Assessment activities increasingly required students to provide reasons for their answers rather than simply present final results. Students were encouraged to describe procedures, explain relationships between mathematical concepts, and provide logical support for their conclusions. In classroom discussions, different solution approaches could be examined and compared. This practice made mathematical reasoning more visible and provided opportunities for students to recognize that mathematical validity depends not only on the final answer but also on the logic and evidence supporting it.

The findings further demonstrated the use of error analysis as an assessment strategy. When students produced incorrect or incomplete solutions, teachers used these responses as opportunities for further learning rather than treating errors solely as evidence of failure. Students were encouraged to identify where their reasoning had changed direction, reconsider assumptions, and examine the mathematical validity of each step. Discussion of errors also enabled other students to evaluate alternative approaches and explain why a particular reasoning process was appropriate or inappropriate. Consequently, errors became valuable sources of information about students' conceptual understanding and reasoning processes.

Comparison of alternative solution strategies was another significant feature of the assessment practices. In several classroom activities, students were encouraged to examine different ways of solving the same mathematical problem. Teachers invited students to compare the efficiency, accuracy, or applicability of different approaches and to explain the circumstances in which a particular strategy might be preferable. This activity required students to make judgments based on mathematical evidence rather than simply reproduce a procedure. The comparison of strategies therefore provided opportunities for students to practice evaluation, decision-making, and mathematical argumentation.

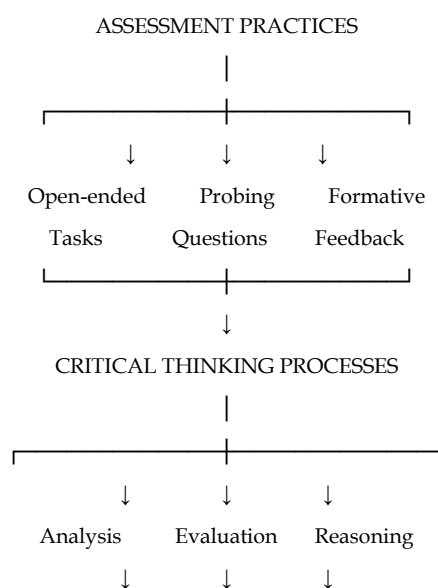
The results also indicate that classroom discussion and peer interaction contributed to the development and assessment of critical thinking. Students were given opportunities to present their solutions, respond to classmates' explanations, and discuss differences between approaches. Peer interaction made mathematical thinking more visible because students had to articulate their reasoning and respond to alternative perspectives. In this context, assessment was not restricted to teacher judgment; classroom dialogue also became a source of evidence regarding students' understanding. Students' responses to peers demonstrated their ability to agree, disagree, question, clarify, and provide mathematical justification.

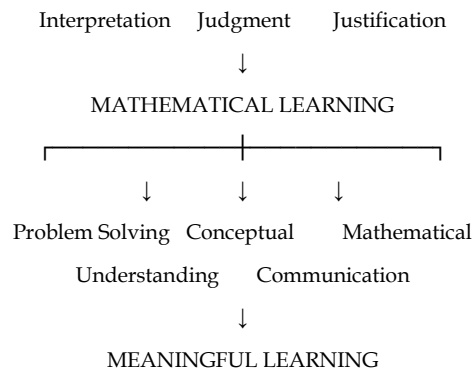
Another finding was the increasing use of formative feedback to support students' mathematical learning. Feedback was provided during and after assessment activities and was directed not only toward the correctness of answers but also toward students' reasoning and problem-solving processes. Teachers used students' responses to identify aspects of understanding that required clarification and encouraged students to revise their solutions when necessary. This process enabled assessment evidence to be immediately connected with subsequent learning activities. As a result, students had opportunities to recognize weaknesses in their reasoning and improve their approaches rather than simply receiving a final score.

The findings further show that assessment practices supported metacognitive reflection among students. Students were encouraged to reconsider the strategies they had used, identify difficulties encountered during problem solving, and evaluate whether their solutions were reasonable. Reflection was particularly visible when students were asked to explain why they selected a particular method or how they might approach a similar problem differently. Such activities encouraged students to become more aware of their own mathematical thinking. Assessment consequently functioned not only as an external evaluation process but also as a mechanism for students to evaluate their own learning.

The relationship between assessment and mathematical problem-solving competence was also evident in the findings. Assessment tasks that required interpretation, strategic selection, justification, and evaluation provided opportunities for students to demonstrate several dimensions of problem solving simultaneously. Students were not simply required to recall mathematical formulas but needed to determine what information was relevant, identify possible solution strategies, implement an approach, and evaluate the resulting answer. These processes demonstrated that assessment for critical thinking can be integrated with mathematical problem solving rather than treated as a separate learning objective.

Figure 1. Relationship Between Assessment Practices, Critical Thinking, and Mathematical Learning





The findings also identified several implementation challenges faced by teachers. Designing assessment tasks that genuinely elicit critical thinking required greater preparation than designing conventional exercises. Teachers needed to consider the level of mathematical difficulty, the possibility of alternative solutions, appropriate questioning strategies, and criteria for evaluating students' reasoning. Classroom time was another challenge because students needed sufficient opportunities to explain, discuss, and revise their solutions. Differences in students' prior knowledge and confidence also influenced their participation in assessment activities. These findings suggest that assessment for critical thinking requires flexibility and sustained teacher facilitation.

Overall, the findings demonstrate an interconnected pattern between assessment practices, critical thinking, and mathematical learning. Open-ended tasks provided opportunities for reasoning; questioning elicited students' thinking; explanation and justification made reasoning observable; error analysis supported reflection; comparison of strategies encouraged evaluation; peer discussion facilitated argumentation; and formative feedback supported improvement. These practices collectively transformed assessment from a predominantly judgment-oriented activity into a learning-oriented process. The findings therefore indicate that assessment for critical thinking in mathematics education is most meaningful when assessment evidence is continuously used to stimulate reasoning, provide feedback, encourage reflection, and support students in constructing deeper mathematical understanding.

Discussion (مناقشة)

The findings demonstrate that assessment in mathematics education can function as a pedagogical process for developing critical thinking rather than merely as an instrument for measuring students' achievement. The observed practices indicate a shift from assessment that primarily emphasizes the correctness of final answers toward assessment that examines students' reasoning, strategies, explanations, and mathematical judgments. This finding reinforces the view that assessment is closely connected to the learning process because the ways in which teachers collect and use evidence of learning influence how students engage with mathematical tasks. When assessment focuses on thinking processes, students are provided with greater opportunities to construct and communicate mathematical understanding rather than simply reproduce procedures (Black & Wiliam, 1998; Wiliam, 2011).

The use of open-ended and non-routine mathematical tasks was particularly important in creating opportunities for critical thinking. Such tasks require students to interpret information, determine appropriate strategies, and consider whether alternative approaches are mathematically valid. Unlike highly structured exercises in which the solution procedure is often predictable, open-ended problems require students to make decisions during the problem-solving process. This finding is consistent with the broader perspective of mathematics education

that emphasizes reasoning, problem solving, and mathematical communication as central components of mathematical competence (NCTM, 2000; Kilpatrick et al., 2001). Open-ended assessment therefore provides teachers with richer evidence of students' thinking while simultaneously creating conditions for students to practice higher-order reasoning.

Teacher questioning emerged as another important mechanism through which assessment stimulated critical thinking. Rather than immediately evaluating an answer as correct or incorrect, probing questions encouraged students to explain how they arrived at a solution and why a particular strategy was appropriate. Such questioning makes students' cognitive processes more visible to teachers and encourages learners to examine their own reasoning. This finding suggests that effective assessment for critical thinking does not necessarily depend on sophisticated assessment instruments; carefully designed classroom questions can also function as powerful assessment tools. In this respect, assessment becomes embedded in classroom interaction and provides continuous information that can be used to guide subsequent learning (Heritage, 2010; Wiliam, 2011).

The emphasis on explanation and justification also demonstrates an important relationship between assessment and mathematical reasoning. Requiring students to explain why a solution is valid moves mathematical learning beyond procedural performance toward the construction of mathematical arguments. Students must identify relevant evidence, establish logical connections, and communicate the basis of their conclusions. This practice is particularly important because mathematical competence involves not only knowing procedures but also possessing the capacity to reason adaptively and justify mathematical claims (Kilpatrick et al., 2001). The finding therefore suggests that assessment criteria should recognize the quality of students' reasoning and justification alongside the accuracy of their final answers.

The use of error analysis provides another important insight into the role of assessment in developing critical thinking. When incorrect responses were treated as evidence of students' thinking rather than simply as failures, errors became opportunities for analysis and reflection. Students could reconsider assumptions, identify weaknesses in their reasoning, and revise their solutions. This approach is consistent with formative assessment principles, in which evidence of student understanding is used to determine appropriate next steps in learning (Black & Wiliam, 1998). More importantly, analyzing errors requires students to evaluate the validity of mathematical reasoning, making the assessment process itself a context for critical thinking.

The comparison of alternative solution strategies further illustrates how assessment can encourage mathematical judgment. When students examine different approaches to the same problem, they must determine whether each strategy is valid, efficient, or appropriate for a particular context. This process involves evaluation rather than simple recall. It also helps students recognize that mathematical problems may sometimes be approached through multiple legitimate pathways. Such experiences support the development of strategic competence and adaptive reasoning, both of which are important dimensions of mathematical proficiency (Kilpatrick et al., 2001). Assessment consequently becomes a means of encouraging students to make reasoned decisions about mathematical methods.

Classroom discussion and peer interaction also contributed to the development of critical thinking by creating a social context for mathematical reasoning. When students presented their solutions and responded to alternative perspectives, they were required to articulate, defend, reconsider, or modify their mathematical ideas. This finding can be understood through the perspective that learning is strengthened through interaction and participation in meaningful social practices. Mathematical understanding is therefore not constructed exclusively through individual problem solving but can also develop through dialogue in which students negotiate and examine different interpretations (Lave & Wenger, 1991). Assessment through classroom dialogue can consequently provide evidence of students' reasoning while simultaneously

extending that reasoning.

The findings concerning formative feedback further emphasize that assessment for critical thinking should lead to action rather than terminate with a score. Feedback that addresses students' reasoning, strategy selection, and explanation provides information that can be used to improve subsequent mathematical work. This interpretation is consistent with research demonstrating that feedback can substantially influence learning when it helps learners understand where they are in relation to learning goals and what they can do to improve (Hattie & Timperley, 2007). Similarly, formative assessment becomes more meaningful when evidence collected during learning is used to modify instruction and support students' next steps (Black & Wiliam, 1998; Wiliam, 2011).

Another significant finding is the emergence of reflection and metacognitive activity within assessment practices. Students were encouraged to reconsider their strategies, identify difficulties, and evaluate the reasonableness of their solutions. This suggests that assessment can contribute to students' awareness of how they think mathematically, not merely what they know. Such reflection is important for developing independent learners who can monitor and regulate their problem-solving processes. From this perspective, assessment for critical thinking involves both teacher assessment of student learning and students' increasing capacity to assess their own reasoning. The integration of reflection therefore strengthens the formative and developmental function of mathematics assessment.

Finally, the findings indicate that assessment for critical thinking is best understood as an integrated classroom practice rather than as a single assessment technique. Open-ended tasks, probing questions, justification, error analysis, strategy comparison, peer discussion, formative feedback, and reflection function most effectively when they are interconnected within the learning process. Nevertheless, implementing these practices requires greater teacher preparation, adequate classroom time, assessment literacy, and the ability to interpret diverse forms of student reasoning. The findings therefore support a broader understanding of assessment innovation in mathematics education: meaningful assessment is not defined primarily by the novelty of its instrument but by its capacity to make student thinking visible, stimulate critical reasoning, and provide evidence that can be used to improve mathematical learning. This perspective positions assessment not at the end of mathematics instruction but at the center of the learning process.

Conclusion (خاتمة)

This study concludes that assessment for critical thinking in mathematics education is most meaningful when it functions as an integral part of the learning process rather than merely as a mechanism for measuring students' final answers. The findings indicate that open-ended and non-routine tasks, probing questions, explanation and justification, error analysis, comparison of solution strategies, classroom discussion, formative feedback, and metacognitive reflection can create opportunities for students to make their mathematical thinking visible. These practices encourage students to interpret problems, analyze information, evaluate strategies, justify mathematical claims, reflect on errors, and make reasoned decisions. Thus, assessment can simultaneously provide evidence of learning and become a pedagogical mechanism that supports the development of mathematical reasoning and critical thinking. This conclusion is consistent with recent research emphasizing that formative assessment in mathematics is most productive when evidence of student learning is actively used to guide subsequent teaching and learning.

The study further suggests that effective assessment for critical thinking should be implemented as an integrated and continuous process in which assessment tasks, classroom

interaction, feedback, and student reflection are closely connected. The contribution of assessment therefore depends not simply on the type of instrument used, but on how teachers design tasks, elicit students' reasoning, interpret their responses, and use assessment evidence to determine subsequent learning activities. This highlights the importance of strengthening teachers' assessment literacy and their capacity to design mathematics assessment that captures processes of reasoning rather than correctness alone. Future studies may extend this research by examining assessment practices across different educational levels, mathematical topics, and classroom contexts, as well as by investigating how sustained formative assessment influences the development of students' critical thinking and mathematical learning over time. Such research is particularly important given the continuing need for context-sensitive approaches to defining and assessing critical thinking in mathematics education.

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