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Critical Thinking as a Pedagogical Tool: Insights from Elementary Mathematics Teachers

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Abstract

Critical thinking (CT) emerges as a fundamental higher-order thinking skill in mathematics education. Teachers' beliefs, perceptions, and definitions regarding CT shape their classroom practices and directly influence students' levels of CT. This study aims to examine in depth mathematics teachers' perceptions of CT, the reflections of these perceptions in their instructional processes, and the meanings constructed in their experiences related to the phenomenon of CT. Design of the study was descriptive phenomenology. The participants consisted of 25 elementary mathematics teachers. As data collection tools, a personal information form and a semi-structured interview form were used to identify the participants' experiences concerning CT. The data obtained through the semi-structured interviews were analyzed using inductive thematic analysis. According to the findings, teachers primarily defined CT as involving questioning, analysis, independent decision-making, and generating alternatives, while metacognitive and affective aspects were less emphasized. CT was considered essential for moving beyond rote learning and for promoting creative problem-solving. Teachers reported that discussion, open-ended questions, and real-life connections fostered CT, though time limits, low motivation, and inadequate assessment tools posed challenges. The use of rubrics and materials was noted to facilitate assessment, with CT viewed as a skill that develops over time.

Keywords: Critical thinking, K-12 teachers, mathematics teachers, higher-order thinking skills

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Introduction

Individuals need to be equipped with 21st-century skills, including communication, collaboration, creativity, and critical thinking (CT) (Akpur, 2025). In this context, CT is recognized as a core competency of the 21st century (Leibovitch et al., 2025) and is regarded as a high-level cognitive process that enables individuals to solve complex problems, evaluate information, and make more informed decisions (Terblanche et al., 2025). As an advanced cognitive skill, CT involves developing self-awareness regarding one's thought processes, questioning the reliability of information sources, constructing coherent arguments, and making thoughtful decisions (Altun & Yıldırım, 2023). Defined as "a reasonable and reflective thinking process focused on deciding what to believe or what to do," CT entails the systematic analysis and evaluation of thinking (Ennis, 2018). CT is not limited to arriving at the correct answer in thinking and problem-solving; it also requires continually reviewing and improving the quality of reasoning (Paul & Elder, 2014). This mental process, particularly in mathematics education, has a wide range of applications and plays a critical role in developing students' problem-solving and reasoning skills (Erdoğan & Kalkan, 2024).

CT is a fundamental high-level thinking skill in mathematics education (Ennis, 2018). Individuals encounter uncertain and complex situations throughout their lives, and in many cases, mathematical analysis is required (Monteleone et al., 2023). Mathematics instruction generally focuses on acquiring knowledge and solving problems. However, deep understanding and effective problem-solving are achievable through strong CT skills (Peter, 2012; Putri et al., 2025). CT develops as students examine mathematical problems, evaluate solutions, and justify results (Romero-Ariza et al., 2024). Reasoning, which lies at the core of CT (Facione, 2011), is also central to mathematics education. Drawing logical inferences from evidence demonstrates a strong connection between CT and mathematics (Ennis, 2018; Rott, 2021). Therefore, it is not sufficient for students to merely recall information. To enhance achievement, it is essential to develop CT skills (Monteleone et al., 2023).

CT is not merely a natural ability; instead, it can be cultivated through targeted instructional strategies and sustained practice (Terblanche et al., 2025). In this context, teachers play a key role in driving change in the development of 21st-century competencies (Romero-Ariza et al., 2024). Especially in disciplines such as mathematics and language education, research has shown that teachers' conceptual clarity about the subject is a determining factor in the development of students' CT skills (Davies & Willing, 2023; Putri et al., 2025). Therefore, teachers' beliefs, perceptions, and definitions of CT shape their classroom practices and directly influence students' levels of thinking (Bezanilla et al., 2023; Leibovitch et al., 2025). Particularly in mathematics education, focusing on how CT is experienced during the problem-solving process and the meanings that teachers attribute to this process has established an essential foundation for supporting the development of CT in mathematics classrooms. For this reason, this research aims to examine in depth elementary mathematics teachers'

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perceptions of CT, how these perceptions are reflected in their instructional practices, and the meanings shaped in their experiences regarding the phenomenon of CT.

Background

The Context of CT

CT is a multidimensional concept defined by philosophers, psychologists, and educators, though no consensus has been reached. Ennis (2018) describes CT as logical, careful, higher-order thinking that guides individuals in deciding what to believe or do, a view aligned with Halpern's (2014) emphasis on purposeful, structured cognitive strategies. This perspective underscores that CT is not merely mental activity but a planned process (Terblanche et al., 2025). Generally, CT comprises cognitive, affective, and knowledge dimensions (Leibovitch et al., 2025). The cognitive dimension encompasses skills such as analysis and evaluation; the affective dimension includes open-mindedness and freedom from bias (Ennis, 2018; Facione, 2011); and the knowledge dimension emphasizes the need for a solid informational base (Paul & Elder, 2014). CT requires problem-solving, inference, and decision-making processes (Huang & Sang, 2023), which are vital for academic and social success in today's complex world (Barak & Shahab, 2023; Ma et al., 2023). Thus, CT is best understood as an integration of skills and dispositions-a purposeful, reflective process shaped by cognitive strategies, affective tendencies, and knowledge (Leibovitch et al., 2025). This multidimensionality makes it essential for lifelong learning and effective decision-making.

The Role and Importance of CT in Mathematics Education

CT is a fundamental aspect of mathematics education, enabling students to analyze, question, and evaluate information beyond procedural knowledge (Romero-Ariza et al., 2024). Ernest (1991) emphasized that CT is grounded in objective, logical examination, which enhances reasoning and inference abilities (Monteleone et al., 2023; Peter, 2012). However, CT does not develop spontaneously. Jablonka (2014) noted that fostering cognitive CT requires intentional curricular design and implementation. Such an approach helps students view mathematics as a tool for thinking and as connected to real life (Jablonka, 2014). Thus, a core goal of mathematics education is to cultivate students' ability to critically examine data and draw meaningful conclusions (Erdoğan & Kalkan, 2024; Salviejo et al., 2024). In classrooms, CT is most evident during argumentation, where students share ideas and discuss justifications-a process that strengthens both conceptual understanding and CT (Romero-Ariza et al., 2024; Wood et al., 2006). Rich mathematical problems further support CT development by requiring students to question information, analyze contexts, and build relationships among data, thereby engaging higher-order processes such as interpretation and evaluation (Putri et al., 2025).

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Teachers' Roles in Developing CT

The importance of encouraging and developing CT in children from an early age has been widely discussed and validated in scientific research (Facione, 2011; Ridwan et al., 2022). The centrality of the teacher's role in strengthening and facilitating CT development is well recognized (Khalid et al., 2021; Romero-Ariza et al., 2024). Teachers' roles in fostering CT skills not only influence the quality of instructional activities but also profoundly affect students' lifelong learning and problem-solving competencies (Terblanche et al., 2025). Research has shown that teachers' beliefs and definitions regarding CT are directly related to the strategies they implement in the classroom (Leibovitch et al., 2025; Ma et al., 2023). For example, while some teachers limit CT to basic cognitive skills, others conceptualize it within a broader framework as a value-based disposition and a way of thinking (Huang & Sang, 2023). Teachers who view CT merely as a set of skills tend to allocate less time for discussion and argumentation, whereas those who see CT as an interdisciplinary and contextual approach are more inclined to use diverse and interactive methods in the classroom (Romero-Ariza et al., 2024). These differing perspectives are a critical factor determining the extent to which students experience CT. Particularly in fields focused on reasoning, such as mathematics, teachers need to regard CT both as an instructional goal and as a pedagogical tool (Erdoğan & Kalkan, 2024; Ridwan et al., 2022).

Teachers need to recognize the importance of mathematical reasoning and, consequently, CT skills (Rott, 2021). When teaching mathematics, teachers themselves must first employ and model CT skills. In this way, students' CT skills can be developed through effective cognitive practices (Putri et al., 2025). In conclusion, how teachers define CT, their perceptions of it, and their beliefs about it exert broad influence, ranging from classroom atmosphere and instructional methods to students' learning experiences and the life skills they acquire (Bezanilla et al., 2023; Huang & Sang, 2023).

Significance and Rationale

CT is a fundamental competency that enables individuals to understand and solve complex problems (Ennis, 2018), and teachers, especially in mathematics education, play a key role in developing this skill (Leibovitch et al., 2025; Romero-Ariza et al., 2024). However, how mathematics teachers define CT, their beliefs about it, and how they incorporate it into their classroom practices have mainly been examined in the literature through quantitative methods (Ismail et al., 2022; Liu, 2023; Tunçer & Sapancı, 2021). In particular, studies conducted in Türkiye have generally focused on identifying pre-service mathematics teachers' CT tendencies and opinions using quantitative self-report scales (e.g., Erdoğan, 2020; Erdoğan & Kalkan, 2024; Özkaya & Aydın-Güç, 2024). This has resulted in limited in-depth knowledge of how teachers conceptualize CT in relation to their own experiences and how they integrate it into their instructional practices.

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Unlike previous studies (e.g., Ismail et al., 2022; Liu, 2023; Tunçer & Sapancı, 2021), this study examines whether teachers conceptualize CT merely as a cognitive skill set or as a multidimensional process encompassing broader pedagogical responsibilities, value transmission, and classroom practices. Furthermore, the present research seeks to provide a deeper understanding beyond self-report scales by examining how teachers conceptualize CT and how this understanding is reflected in their approaches and attitudes toward mathematics instruction. In this way, practical recommendations can be developed to inform both teacher education and curriculum design. In this respect, the study is expected to address the lack of qualitative research on in-service mathematics teachers and to make a significant contribution to the literature by revealing teachers' experiences related to CT.

Studies have emphasized that teachers' beliefs and perceptions can evolve over time and that this transformation is directly reflected in the quality of instruction (Bezanilla et al., 2023; Leibovitch et al., 2025). Nevertheless, qualitative studies that explore in depth the experiences of in-service mathematics teachers remain scarce (e.g., Davies & Willing, 2023; Innabi & El-Sheikh, 2007; Koç-Erdamar & Bangir-Alpan, 2017; Ridwan et al., 2022). Moreover, in the literature, CT has often been assessed within the scope of general teacher competencies, which has limited its specific examination in fields such as mathematics, where reasoning occupies a central role. However, research findings demonstrate that CT improves the quality of students' thinking in mathematical problem-solving processes and that teacher perceptions play a decisive role in this context (Putri et al., 2025; Romero-Ariza et al., 2024). By focusing on teachers' experiences of CT in mathematics education, this study seeks to address a thematic gap in the literature.

Method

Model

This study employed a qualitative research approach using a phenomenological design. Phenomenology aims to understand individuals' perceptions, experiences, and the meanings they attribute to a phenomenon (Moustakas, 1994). Specifically, descriptive phenomenology was used to explore elementary mathematics teachers' perceptions of CT, to describe their experiences, and uncover the essence of the phenomenon (Moustakas, 1994; Tomaszewski et al., 2020). The researcher brackets personal biases and focuses on describing the phenomenon as it is, based on participants' experiences (Lim, 2024). In this study, CT was considered a phenomenon experienced and defined by teachers, and the aim was to examine their perceptions and experiences in depth. This approach aligns with the core principles of descriptive phenomenology, which focuses on describing the phenomenon as experienced by individuals.

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Participants

The study participants were 25 elementary mathematics teachers working at a provincial center in the Eastern Anatolia Region. In phenomenological studies, participants who have experienced the phenomenon in question in depth are preferred, and the number generally ranges from 5 to 25 (Creswell & Poth, 2016). In this study, maximum variation sampling, a purposive sampling method, was used to identify teachers with extensive experience in CT. This method contributes to interpreting the findings within a broader context (Creswell & Poth, 2016). To assess participants' experiences with CT, a personal information form was used. The forms were distributed to 185 elementary mathematics teachers at the provincial center, and 154 teachers responded. The researchers evaluated the responses. Using maximum variation sampling, the study included the perspectives of teachers with diverse genders, ages, educational backgrounds, and professional experiences. The criteria determined for participant selection were as follows:

Professional experience: Having at least five years of teaching experience.

Relevance to CT: Incorporating CT into their lessons or having experience indicating they had received training on this topic.

Professional awareness: Possessing the knowledge and skills demonstrating an understanding of the importance of CT.

Willingness to participate: Voluntarily participating in the interview process with an understanding of the scope and objectives of the study.

Based on these criteria, 25 teachers with experience in CT and a willingness to participate voluntarily were selected as study participants. The teachers' real names were not used; they were coded as T1-T25. Based on these criteria, 25 teachers with experience in CT and a willingness to participate voluntarily were selected as study participants. 72% of the participants were female, and 28% were male. In terms of age, 48% were between 31–35 years, 28% between 36–40 years, and 20% were over 41. Regarding professional experience, 52% had 6–10 years of teaching experience. Regarding educational background, 60% held a bachelor's degree, and 40% held a master's degree. This demographic diversity enriched the study by offering multifaceted perspectives on critical thinking. The teachers' real names were not used; they were coded as T1-T25.

Instruments

In this study, a personal information form was used initially to identify participants. The form was designed to elicit participants' experiences with CT, and preliminary screening questions were administered. Designed as open-ended and exploratory, the questions aimed to reveal teachers' awareness and practices regarding CT. Expert opinions were consulted during this process (two academics with a doctorate in mathematics education).

To elicit teachers selected through purposive sampling's perceptions and opinions on CT, a semi-structured interview guide was used. The researchers developed this form. During its development, qualitative studies on CT were first reviewed (e.g., Altun & Yıldırım, 2023; Bezanilla et al., 2019, 2023; Davies & Willing, 2023; Innabi & El-Sheikh, 2007; Koç-Erdamar & Bangir-Alpan, 2017; Lee et al., 2024; Ma et al., 2023; Sachdeva & Eggen, 2021). In line with the study's purpose, a draft form comprising 14 questions was created and submitted to experts for content validity assessment. Based on expert feedback, some questions were removed, and the wording of others was revised. Additionally, to evaluate the clarity of the form, feedback was obtained from two mathematics teachers, and a pilot interview was conducted. Following the pilot application, the final version of the interview form was determined.

Data Collection Process

Ethical approval and institutional permissions were obtained before data collection. Semi-structured interviews were used, offering a flexible yet guided format that is ideal for phenomenological research and enables in-depth exploration of participants' perceptions (Merriam & Tisdell, 2015; Robinson, 2023). Participation was voluntary, and informed consent was secured from all participants. During interviews, prompts such as "Please explain" encouraged elaboration. Interviews were conducted face to face in locations chosen by participants, averaged 18 minutes, and were audio-recorded to capture rich, context-specific data.

Data Analysis

An inductive thematic analysis method was used to analyze the qualitative data. Thematic analysis aims to systematically examine data to generate themes and address the research questions through these themes (Braun & Clarke, 2006). An inductive approach was adopted, with themes derived directly from the data. The data analysis process was conducted following the steps proposed by Braun and Clarke (2006). In the first stage, the interview transcripts were read repeatedly to gain familiarity with the data, and initial notes were taken. In the second stage, meaningful data segments were coded, and prominent concepts were identified. The coding process was conducted in a data-driven manner, free of preconceived biases. In the third stage, the codes were grouped according to shared meanings to form potential categories. In the fourth stage, the categories were reviewed, their adequacy in representing the data set was assessed, and adjustments were made as necessary. In the fifth stage, the categories were named and defined, and sub-themes were clarified. In the final stage, the themes were reported holistically, and the findings were supported with participant quotations.

Trustworthiness and Reliability in Qualitative Research

Lincoln and Guba's (1985) framework for trustworthiness in qualitative research includes credibility, dependability, confirmability, and transferability (as cited in Lim, 2024). These criteria guided this study to ensure valid and reliable data collection and interpretation. To enhance credibility, member checking was conducted by presenting participants with their statements for verification. Open-ended interview questions allowed participants to express their views freely. Thick description was employed to convey context and to support the accuracy of the findings (Lim, 2024). Detailed participant statements, comprehensive contextual information, and direct quotations were provided to substantiate themes.

For dependability, the research process was systematically planned and documented to facilitate replication. Detailed reporting of the interview protocol and coding procedures ensured transparency. Triangulation was employed to enhance reliability by incorporating multiple perspectives and minimizing bias (Lim, 2024). A second researcher independently coded the data. Inter-rater agreement, measured with Cohen's Kappa, was 88%, indicating high reliability (Landis & Koch, 1977). Discrepancies were resolved through discussion until consensus was reached. To ensure confirmability, reflexivity was applied to monitor potential researcher bias, and interpretations were supported with direct participant quotations. An audit trail documented all stages of the study, and member checking was conducted to validate findings. For transferability, detailed descriptions of the research context and participants' demographics were provided to help readers assess applicability to other settings.

Results

In this section, the findings related to the five main themes derived from the inductive thematic analysis of teachers' views are presented.

Theme 1 – Conceptualization of CT

Within this theme, how teachers define CT was examined. Based on the prominent concepts in their definitions, the categories and corresponding codes are presented in Table 1.

Table 1. Findings related to the conceptualization of CT

Codes	Teachers
Questioning and analyzing	T1, T4, T5, T8, T9, T6, T13, T22
Creative and original thinking	T10, T15, T18, T24, T25
Developing independent thinking	T3, T14, T20, T23, T24,
Developing different perspectives	T2, T7, T11, T21
Evaluating and decision-making	T6, T12, T17, T22
Developing social awareness	T16, T19

Most of the teachers defined CT as the process by which individuals make sense of information through questioning and evaluation. The participants emphasized that this involves not only acquiring knowledge but also analyzing and reconstructing it. T1 described this approach as "*not accepting information as it is, but evaluating it through questioning,*" highlighting the importance of intellectual depth. Another prominent aspect was the connection between CT and creative thinking. Teachers stated that this skill contributes to students' ability to reconstruct knowledge, produce original solutions, and develop diverse ideas. T10 defined CT as *"the ability to synthesize information and recreate it from a creative perspective."*

Participants also stressed that CT supports independent decision-making, personal reasoning, and individual idea generation. They noted that this process enables individuals to trust their own thinking abilities. T23 described this as *"a skill that enables individuals to reach knowledge through their reasoning abilities."* Some teachers noted that CT encourages considering events from multiple perspectives and facilitates flexible thinking. T21 described this as *"looking at an issue from different angles,"* emphasizing the importance of going beyond established patterns. It was also stated that CT has a guiding role in evaluation and decision-making processes. T6 explained this skill as *"a way of thinking that supports reasoning and analysis processes."* Finally, some participants emphasized that CT increases social awareness and fosters a sense of social responsibility. T16 described this relationship as *"identifying shortcomings in social life and developing solutions."*

Theme 2 – The Role and Importance of CT in Mathematics Education

The findings related to Theme 2 focused on the role and function of CT in mathematics instruction (Table 2).

Table 2. Findings related to the role and importance of CT in mathematics education

Category	Codes	Teachers
The function of CT in mathematics instruction	Learning based on thinking rather than memorization	T3, T4, T5, T6, T8, T18, T23, T24
	Intellectual depth in problem solving	T3, T4, T8, T10, T12, T18, T24
	Inquiry-oriented instructional processes	T5, T16, T19, T15, T25
	Mathematics as a fundamental thinking skill	T1, T2, T7, T9, T18
Understanding from different perspectives	Viewing events from different perspectives	T13, T14, T17, T19, T21, T22
	Developing alternative solutions	T4, T11, T17, T20
	Relating to everyday life	T8, T13, T18

Most of the teachers stated that CT goes beyond rote approaches and requires discovering the reasoning behind mathematical rules. T4 emphasized this point by saying, *"No matter how formulaic a formula is, it should definitely not be based on memorization. The student needs to find their own way to solve it."* The participants expressed that CT helps students take deliberate steps in the problem-solving process. T12 highlighted this relationship, stating, *"Problem-solving requires analyzing processes, questioning, and synthesizing. Therefore, CT is directly related to problem-solving."*

Some teachers also noted that CT provides significant benefits for teachers and facilitates a more critical evaluation of curricula. T5 explained this transformation by stating, *"Sometimes the curriculum may be incomplete or excessive. CT helps us notice such deficiencies and reach more* *effective methods."* The participants emphasized that CT is an indispensable skill in mathematics instruction, enabling students not only to perform calculations but also to arrive at solutions by considering different approaches. T2 stated, *"CT is essential in mathematics. You can't just do calculations without thinking; you can do them, but you won't know what you are doing."*

Many teachers expressed that CT makes it easier for students to approach problems and situations from different perspectives. T11 underscored the importance of this process by saying, *"Not every student thinks the same way; different solution paths are important. This develops through CT."* Additionally, some participants emphasized that CT contributes to students' development of their own solution strategies and to their self-confidence. T4 stated, *"I present multiple ways of solving problems to students and expect them to develop their own methods. CT is at the center of this process."* Finally, the teachers noted that this skill facilitates the transfer of mathematical knowledge to everyday life. T8 remarked, *"A student who cannot think critically in mathematics will struggle to understand the data they encounter in daily life, which limits their ability to solve problems."*

Theme 3 – Characteristics of Critically Thinking Students and Teachers

Theme 3 focused on the characteristics of critically thinking students and teachers in mathematics classes, and the findings are presented in Table 3.

Table 3. Findings related to the characteristics of critically thinking students and teachers

Category	Codes	Teachers
Inquisitive and open-minded student	Asking why and how questions	T6, T9, T13, T21
	Being open to idea	T9, T14, T24, T15
	Not immediately accepting given information	T13, T19, T25
Solution-focused, analytical student	Developing alternative solutions	T5, T14, T20, T25
	Establishing cause-and-effect relationships	T4, T8, T10, T19
	Solving problems quickly and logically	T2, T10, T17
Creative, original problem-solver	Creating one's own solutions	T1, T3, T12, T14, T18, T25
	Developing different perspectives	T3, T7, T17, T24
	Generating original ideas	T5, T7, T18, T22
Expressive and socially adaptable student	Expressing oneself clearly and accurately	T11, T18, T23, T24
	Collaborating effectively within a group	T16, T24, T25
	Being respectful and tolerant of others' ideas	T9, T18, T24
Teacher open to questioning	Being open to ideas and change	T1, T2, T6, T11, T12, T25
	Questioning instructional processes	T4, T12, T13, T17, T20
	Being open to learning from students	T6, T11, T15, T7, T22
	Being sensitive to students' perspectives	T5, T9, T24

Teachers stated that students who develop CT become inquisitive, solution-oriented, creative, and socially competent individuals. It was noted that these characteristics span a wide spectrum, from attitudes toward mathematics lessons to communication skills. Most teachers described critically thinking students as individuals who frequently ask "why" and "how" questions and who question the information they receive. T13 stated, *"Children who constantly question, ask why, and do not immediately accept given information tend to be more inclined to CT."* Solution-oriented and analytical thinking skills were also frequently emphasized. T25 explained this by saying, *"These students can also search for alternative solutions. They want to learn different methods for solving problems."* Creativity was noted to develop alongside CT, and T5 described this relationship by stating, *"When faced with a new problem, they can produce original ideas. Instead of simply memorizing information, they can apply it in new ways."*

Participants expressed that critically thinking students are successful in expressing themselves and engaging in social interactions. T24 remarked, *"They have stronger relationships with their peers. Because they are solution-oriented, they can communicate effectively."* According to the teachers, a critically thinking mathematics teacher should have an inquisitive, open-minded, and sensitive approach. T1 highlighted this by saying, *"You need to have strong communication with children; being open-minded is important rather than being a strict teacher."* Openness to innovation was also identified as essential. T11 expressed this by stating, "*Life is constantly evolving; there is so much we can learn even from children."* It was noted that an inquisitive attitude also enables teachers to evaluate their instructional processes critically. T12 said, *"We must look at topics from different perspectives and question them."* Some teachers emphasized that teachers are figures who also learn from their students. T15 described this by stating, *"I can improve myself by learning from my students."* Finally, sensitivity to students' perspectives was frequently mentioned. T9 remarked, *"You should consider the student's perspective; every child has a different learning style."*

Theme 4 – Development of CT Skills

Theme 4 focused on teachers' perceptions regarding whether CT can be developed in mathematics classes, and the findings are presented in Table 4.

Table 4. Findings related to the development of CT skills in mathematics classes

Category	Codes	Teachers
Practices that activate CT	Different perspectives	T8, T16, T18, T19, T20, T21
	Questioning and discussion	T6, T7, T12, T20, T22
	The necessity of thinking and meaning making	T1, T8, T18, T22, T25
	Relating to daily life	T13, T18, T23, T24
	Collaboration and interaction	T7, T9, T24
Factors that limit CT	Lack of time	T5, T6, T9, T10, T14, T15
	Language proficiency and reading habits	T2, T3, T11
	Lack of motivation	T4, T13, T17

Mathematics teachers stated that CT is a fundamental skill that should be developed due to the nature of the subject itself. The teachers emphasized the importance of an instructional environment based not on memorization but on thinking. Some participants reported that CT enables students to view situations from multiple perspectives. T15 stated, *"It is very important to help them gain the ability to think differently."*

Questioning and discussion techniques were highlighted as effective in eliciting students' thinking. T12 explained the impact of this approach by saying, *"By asking questions, we can guide students' thinking processes."* Discussions were noted to help students express their ideas and deepen their thinking by engaging with different viewpoints. Teachers stressed that mathematics is not merely about performing operations but requires thinking skills. T1 remarked, *"Instead of giving information directly, you need to draw students into the process."*

Participants stated that problems connected to daily life support the development of CT. T18 said, *"When we relate math lessons to real-life problems, CT skills develop."* Additionally, the importance of group work and peer interaction was emphasized. T9 illustrated these methods by stating, *"Brainstorming and collaborative learning methods can develop CT."* While teachers agreed that CT can be developed, they also emphasized that specific barriers limit the process. The demanding curriculum and time constraints were noted to make it difficult to devote sufficient attention to these skills. T6 stated, *"I wish we had more time or the curriculum were slightly lighter; this process would be much better."* Similarly, T14 highlighted the impact of crowded classrooms.

It was also expressed that deficiencies in language skills and insufficient reading habits limit CT. T2 emphasized the importance of reading by stating, *"Reading books supports multidimensional thinking and understanding questions."* Teachers noted that low motivation reduces students' participation in problem-solving processes. T4 underscored the importance of a supportive environment by stating, "*When children gain that confidence, they start making logical explanations."* These views indicate the extent to which a conducive environment and motivation support the development of CT.

Theme 5 – Assessment of CT

The theme of assessing CT focused on teachers' perceptions regarding the observation and evaluation of CT in mathematics classes (Table 5).

Teachers stated that, by its nature, CT presents challenges in the assessment process. Because this skill is primarily based on internal processes and has an abstract structure, conducting clear and reliable evaluations is difficult. T3 highlighted this issue by saying, *"CT is more about synthesizing and analyzing. It's not very easy to measure; it's not clear because of that,"* drawing attention to the difficulty of making thinking visible.

Table 5. Findings related to the assessment of CT in mathematics classes.

Category	Codes	Teachers
Classroom reflections of CT	Behaviors observed during the course	T1, T4, T9, T10, T18
	Thinking pathways revealed through questions	T6, T7, T12, T24
	Attempting to solve using different approaches	T5, T8, T19, T25
The development process of CT	Understanding through open-ended questions	T9, T11, T23, T24, T16
	Processes developing over time	T2, T13, T20, T21
The difficulty of assessing CT	The difficulty of measuring thinking	T3, T10, T14, T22, T17
	Assessment using rubrics	T13, T15, T20, T25
	Observing thinking through materials	T15, T23

Teachers' views revealed that structured tools contribute to the assessment of CT. In particular, rubrics were reported to allow for the systematic analysis of students' thinking processes. T20 described this by stating, *"With rubrics, at least it becomes more feasible to assess this way of thinking under specific headings."* Rubrics enable teachers to observe and compare students' CT skills against defined criteria.

Teachers also emphasized that materials function as supportive tools in the assessment process. Visual and hands-on materials that enable students to express their thinking make teachers' observation of their reasoning easier. T15 explained the role of materials in assessment by stating, "*With the materials I prepare, I can see more clearly how the student is thinking."* These statements indicate that CT is regarded not as an output that can be directly scored but as a mode of thinking that can be monitored through teacher observation, structured tools, and process-oriented assessment.

Discussion

The findings indicate that teachers predominantly defined CT as questioning, analysis, and independent thinking. While participants described CT as reconstructing rather than passively accepting information and associated it with creativity and social awareness, their definitions remained only partially structured and primarily cognitive. This aligns with Facione's (1990) conception of CT as involving skills such as interpretation, analysis, inference, evaluation, and self-regulation. Consistent with Altun and Yıldırım (2023) and Ma et al. (2023), higher-order constructs such as self-regulation and epistemic awareness were largely absent. Huang and Sang (2023) and Terblanche et al. (2025) similarly observed that pre-service teachers often hold superficial understandings of metacognitive and applied dimensions. Bezanilla et al. (2023) and Pnevmatikos et al. (2023) further noted a tendency to define CT abstractly and in virtue-based terms, indicating a persistent conceptual limitation. Nonetheless, teachers' emphasis on creative and original thinking is noteworthy. Participants' references to reconstructing knowledge and generating new solutions suggest a view of CT as both analytical and productive, in line with Romero Ariza et al. (2024). The focus on independent decision-making and reasoning also reflects positive awareness, resonating with Bezanilla et al. (2019) and

Leibovitch et al. (2025), who highlight CT's connection to self-efficacy. Finally, associating CT with social responsibility underscores the role of cultural context. As Barak and Shahab (2023) observed, CT can be framed as a socially oriented competence. Expressions such as "developing solutions in social life" indicate awareness of ethical responsibility and cultural sensitivity, echoing Ridwan et al. (2022) and Huang and Sang (2023).

Teachers viewed CT as essential for mathematics instruction, enabling students to move beyond rote learning. This perspective partly aligns with Innabi and Sheikh (2007), who found that teachers linked CT to problem-solving but often lacked a holistic pedagogical conceptualization. Participants emphasized CT's role in fostering inquiry-based learning and multiple solution strategies, consistent with Putri et al. (2025) and Ridwan et al. (2022), who noted CT's contribution to lasting understanding and problem-solving skills. Teachers also associated CT with questioning accuracy and the justification of solutions, consistent with Rott's (2021) findings linking CT to reasoning. Similarly, Liu (2023) reported that teachers perceive CT as strengthening students' logical thinking, a finding also highlighted by participants. Moreover, defining CT as connecting mathematics to real life aligns with the work of Romero-Ariza et al. (2024) and Tunçer and Sapancı (2021), who emphasized the incorporation of authentic problems into instruction. Expressions such as "transferring mathematics to life" further illustrate this orientation.

In this study, teachers described critically thinking students as inquisitive, creative, open-minded, and communicative. In contrast, they defined critically thinking teachers as role models who reflect on their practice and remain open to learning. This indicates that CT was conceptualized not only cognitively but also through social, emotional, and ethical dimensions. Teachers' emphasis on inquiry and multiple perspectives aligns with Altun and Yıldırım (2023), Davies and Willing (2023), and Paul and Elder (2014), who highlighted curiosity and openness as central to CT. The association of CT with creativity echoes findings reported by Terblanche et al. (2025), Peter (2012), and Akpur (2025), which emphasize the role of innovative thinking and problem-solving. Participants also underlined the social aspect of CT, linking it to communication, collaboration, and empathy, consistent with Ennis (2018) and Davies and Willing (2023). References to "tolerance for different opinions" further illustrate this communal perspective. Finally, the view that teachers must model CT by questioning their own practices reflects pedagogical leadership perspectives (Koç-Erdamar & Bangir-Alpan, 2017; Leibovitch et al., 2025). This aligns with Facione's (2011) assertion that teachers share responsibility for fostering CT and with Rott's (2021) emphasis on integrating CT with self-regulation and continuous professional development.

In this study, teachers described the development of CT in mathematics as both essential and challenging. They believed CT could be fostered through encouraging diverse perspectives, questioning, real-life connections, and collaboration, but cited time constraints, low motivation, and limited language proficiency as significant barriers. Teachers' preference for discussion and inquiry aligns with Campo et al. (2023), who found active methods such as debate and project-based learning effective for CT, and with Bezanilla et al. (2019), who highlighted discussion as key to argumentation and evidence-based reasoning. Similarly, Lee et al. (2024) reported that guided inquiry and group work are widely used but face sustainability challenges. This study confirms that, although teachers value such strategies, practical constraints impede their consistent application. The challenges identified mirror findings from recent research. Teachers reported uncertainty in implementation and assessment, consistent with Khalid et al. (2021), who noted curriculum pressure and performance-focused evaluations as obstacles. Likewise, Bezanilla et al. (2019) and Campo et al. (2023) observed that instructors often struggle to select suitable pedagogical approaches. Low motivation was also cited as a limiting factor, echoing Bezanilla et al. (2019) and Lee et al. (2024). Finally, while Andreucci-Annunziata et al. (2023) emphasized the need to integrate the cognitive and affective dimensions of CT through long-term approaches, this study shows that teachers primarily view CT as a cognitive skill, overlooking its dispositional aspects. This suggests the multidimensional nature of CT has yet to be fully internalized.

The findings reveal that teachers view assessing CT in mathematics as a multidimensional and challenging process. They reported that CT becomes visible through open-ended questions, alternative solutions, and students' justifications. However, its abstract nature and the need for extended observation make assessment difficult, and the development of standardized approaches remains problematic. While rubrics and materials were seen as helpful, student motivation was also cited as a key factor. Teachers' emphasis on justification and inquiry aligns with Le and Chong (2024) and Facione (2011), who identified evidence-based reasoning as a primary indicator of CT. This study further shows that teachers perceive CT as a process-oriented competence requiring sustained development, consistent with Liu et al. (2014) and Paul and Elder (2014). Reports of challenges in measuring CT echo Le and Chong's (2024) and Ennis's (1993) findings that standard tests are inadequate and that observation-based tools are necessary. Teachers' views that rubrics help structure and assess CT align with Brookhart's (2010) conclusion that rubrics increase transparency and clarify students' progress.

Conclusion

This study examined mathematics teachers' perceptions of CT, their classroom practices, and their assessment approaches. The findings indicate that teachers primarily define CT in terms of cognitive dimensions, such as questioning, analysis, generating alternative solutions, and making independent decisions. However, higher-level metacognitive and affective components were expressed to a more limited extent. Teachers reported that CT emphasizes problem-solving, creativity, and inquiry over rote memorization in mathematics lessons. Additionally, they described the critically thinking student as a curious, versatile individual with a sense of social responsibility. They emphasized that teachers themselves should be open to learning and willing to reflect on their practices. It was noted that discussion environments, questioning strategies, and the connection of content to daily life were considered adequate in the instructional process. In contrast, factors such as time constraints, lack of motivation, and limited language proficiency were seen as limiting. Regarding assessment processes, teachers noted that CT is a skill that develops over the long term, that standard measurement tools are inadequate, and that rubrics and materials can partially address this gap. In conclusion, teachers' perspectives on CT appear positive and multidimensional, but it is evident that more systematic support and guidance are needed in both practice and assessment. The contribution of this study lies in providing a detailed account of the use of CT in mathematics instruction, based on teachers' experiences.

Limitations and Recommendations for Future Research

This study was conducted with a limited number of mathematics teachers in a single province, which limits the generalizability of the findings to other contexts. Additionally, data collection relied solely on semi-structured interviews; therefore, methodological triangulation could not be achieved through methods such as classroom observations, document analysis, or student interviews. Future research should involve teachers from diverse regions and school types to examine how cultural and institutional contexts shape perceptions of CT. Employing mixed-method designs and multiple data sources-such as observations, student work, and teacher journals-would improve credibility and depth (Brookhart, 2010). Longitudinal studies could offer insights into the long-term effects of CT-focused instruction and teachers' evolving practices. Additionally, a more detailed examination of the metacognitive and affective dimensions of CT is recommended.

Recommendations for Practitioners and Policy Makers

The findings indicate that teachers view CT as integral to mathematics instruction but face challenges, including time constraints, assessment difficulties, and low motivation. To address these issues, it is important to design interdisciplinary, practice-oriented in-service training programs to help teachers develop CT-focused lesson plans. Additionally, empirically testing the effects of professional development on teachers' knowledge, attitudes, and practices would be valuable. Expanding the use of instructional materials, digital tools, and assessment rubrics that support CT is also recommended. Developing and evaluating alternative assessment tools to measure CT skills reliably is essential (Liu et al., 2014; Facione, 2011). Providing more flexible scheduling to allow time for discussion and problem-based learning could further facilitate CT integration. Updating teacher education programs to deepen pre-service teachers' conceptual understanding of CT is necessary. At the policy level, defining CT not only as an academic skill but also as a means of fostering social responsibility and ethical awareness can help to revise curricula and assessment systems more holistically.

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Policy Implications

The findings indicate that policy initiatives aiming to strengthen critical thinking in mathematics should not be limited to declaring this competence in curriculum texts; they should also make it instructionally and institutionally feasible by aligning curriculum scope, teacher learning, and assessment. Teachers tend to conceptualize critical thinking primarily through cognitive operations such as questioning, analysis, independent judgment, and generating alternative solutions, which signals a generally positive orientation toward higher-order thinking but also suggests that metacognitive and dispositional dimensions may remain under-articulated in everyday practice. At the implementation level, participants repeatedly point to dense curricular expectations and limited instructional time as structural constraints that reduce opportunities for discussion, argumentation, and problem-based learning, implying that policy should consider reducing content overload and creating explicit time and flexibility for reasoning-focused instruction. In parallel, the study underscores the need for practice-oriented professional development that goes beyond awareness-raising and supports teachers in designing lessons that elicit justifications, multiple solution pathways, and meaningful connections to real-life contexts. Assessment emerges as a particularly salient policy lever: teachers describe critical thinking as difficult to measure because it is partly internal and develops over time, yet they also identify rubrics, open-ended tasks, and materials that make thinking visible as workable supports. These insights suggest value in system-level guidance that provides shared rubrics, annotated exemplars, and performance tasks that prioritize reasoning evidence, thereby increasing coherence between instructional aims and evaluation practices. Finally, teachers' references to motivation, language competence, and reading habits as barriers imply that critical thinking in mathematics is intertwined with broader literacy and classroom culture conditions; accordingly, policies on learning resources, literacy development, and student engagement should be connected to reasoning and argumentation goals rather than treated as separate agendas.

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Conflict of Interest

No potential conflict of interest was declared by the authors.

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Ethical Statement

The research received ethical approval, confirming its adherence to relevant guidelines and regulations. Specifically, for this study, approval was granted by the Fırat University Social and Human Sciences Scientific Research Ethics Committee (dated 04.05.2023, meeting no:2023/09 decision no:19)

Credit Author Statement

Author 1: Conceptualization, Methodology, Validation, Writing – Review & Editing, Supervision, Visualization. *Author 2:* Formal Analysis, Resources, Investigation, Methodology, Writing – Original Draft Preparation

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