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Original Article

An Analysis of Critical Thinking Disposition of Prospective Mathematics Teachers in Mathematical Problems Solving

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Abstract: Truth-seeking and open-mindedness are core dispositions of critical thinking, particularly in the context of mathematical problem solving. This study examines the critical thinking dispositions of prospective mathematics teachers when solving problems containing contradictory information and incomplete data. Specifically, it investigates behavioral tendencies related to truth-seeking and open-mindedness.This qualitative exploratory study involved 15 prospective mathematics teachers. Data were collected through written tests, direct observations, and semi-structured interviews. To enhance validity, methodological triangulation was employed by comparing findings across these three data sources to ensure consistency and credibility. The findings indicate that the participants generally did not demonstrate strong truth-seeking dispositions. Most participants failed to question the validity or completeness of the information presented and tended to respond procedurally without critically examining contradictions or missing data. These results suggest that procedural competence does not necessarily reflect the presence of critical thinking dispositions. The study highlights the need for instructional strategies that explicitly foster truth-seeking and open-mindedness in mathematics teacher education.

Keywords :
Ttruth-seeking; Open-mindedness; Prospective mathematics teachers; Contradictory mathematical problems; Mathematical problem solving

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INTRODUCTION

Critical thinking is an essential skill that enables individuals to reason, evaluate, and analyze deeply, thereby improving the quality of judgment in problem situations by avoiding premature conclusions (Taghinezhad, Azizi, & Shahmohammadi, 2019; As'ari, Mahmudi, & Nuerlaelah, 2017). Its development can be facilitated through performance-based and work-based assessments that emphasize problem-solving grounded in real-world contexts and prior experiences (Hyytinen & Toom, 2019; Shavelson, 2018; Zahner & Ciolfi, 2021). Conceptually, Ennis (1985) defines critical thinking as reflective and rational thinking focused on deciding what to believe or do, encompassing not only cognitive skills but also a dispositional dimension the consistent tendency to engage reflectively in decision-making and problem-solving (Chukwuyenum, 2013; Rivas & Saiz, 2016; Turabik & Gün, 2016). The literature identifies seven components of critical thinking disposition: truth-seeking, open-mindedness, analyticity, systematicity, self-confidence, inquisitiveness, and maturity (Lampert, 2007; Bakir, 2015; Karagöl & Bekmezci, 2015; Darby & Rashid, 2017).

Despite the crucial role of truth-seeking and open-mindedness in helping prospective mathematics teachers respond to contradictory, existing studies emphasize critical thinking skills over their dispositional dimension (Yorgancı, 2016; Çelik & Özdemir, 2020; Kuşçu & Erdoğan, 2024), necessitating further investigation into how these dispositions manifest in problem-solving, as teachers often face challenges applying critical thinking in mathematical contexts (Smith & Thompson, 2021; Lee & Hong, 2019). Research indicates that cultural and educational contexts influence these dispositions (González & Romo, 2018; Ahmad & Rahman, 2022), while structured problem-solving, reflective learning, and non-routine problems can enhance them (Al-Nuaimi & Al-Jaberi, 2020; Brown & Evans, 2019; Davis & Reid, 2021; Liu & Cheng, 2018; Walters & Bartlett, 2021), alongside self-confidence and prior mathematical knowledge (Parker & Cohen, 2020; Singh & Gupta, 2023; Hart, 2019).

Assessment of critical thinking dispositions using validated instruments has become a common approach to evaluate and guide teacher education programs (Moreno & Villanueva, 2022; Patel & Sharma, 2019; Garcia & Liu, 2021), with studies indicating that sustained engagement in reflective problem-solving tasks and pedagogical frameworks combining mentorship with authentic problem-solving scenarios systematically enhance critical thinking dispositions and prospective mathematics teachers' classroom effectiveness (Nguyen & Tran, 2023; Yüksel, Sarı-Uzun, & Dost, 2013; Kurniati, Purwanto, As'ari, & Sa'dijah, 2020; Kurniati & As'ari, 2018, 2019; Wulan & Ilmiyah, 2022; Cahyono, Rohman, & Setyawati, 2022). The literature consistently emphasizes that fostering critical thinking dispositions particularly truth-seeking and open-mindedness is essential for developing pre-service teachers capable of tackling complex mathematical problems, reflecting the growing recognition of critical thinking as a core competency in mathematics education (Yorgancı, 2016; Çelik & Özdemir, 2020; Kuşçu & Erdoğan, 2024). Research indicates that prospective teachers with well-developed dispositions are better prepared to analyze student thinking, adapt instructional strategies, and respond to diverse learning needs (Brown & Evans, 2019; Parker & Cohen, 2020); therefore, teacher education programs should embed sustained engagement with non-routine problems and reflective practices to strengthen these foundational dispositions (Kurniati *et al.*, 2020; Walters & Bartlett, 2021).

Given that critical behavior is fundamentally grounded in truth-seeking and open-mindedness (Dwyer, Hogan, & Stewart, 2014; Ordem, 2017; Kurniati & As'ari, 2021;

Choy & Oo, 2012; Stanovich, 2016; Ennis, 1996) yet mathematics students exhibit low levels of these dispositions despite their theoretical importance (Lampert, 2007; Akgun & Duruk, 2016), with research emphasizing skills over dispositional manifestations, problems containing contradictory or incomplete information provide a meaningful context for examining how these dispositions emerge (Ennis, 1996; Facione, 1990; King & Kitchener, 1994; Kuhn, 1999), but limited research has investigated this among prospective mathematics teachers (Kurniati & As'ari, 2021; Putri *et al*., 2020; Paul & Elder, 2006; Willingham, 2008), necessitating this study to analyze their manifestation and contribute to understanding the dispositional dimension of critical thinking in mathematics teacher education (Halpern, 2014; Siegel, 2017).

This study aims to examine the behavioral tendencies of prospective mathematics teachers when solving problems containing contradictory and incomplete information, as reflected in the critical thinking disposition indicators of truth-seeking and open-mindedness, by addressing how both dispositions are manifested in this problem-solving context. The contributions of this study are threefold: it provides an empirical description of how truth-seeking and open-mindedness emerge during problem-solving with contradictory and incomplete information; identifies characteristic patterns of these dispositions among prospective mathematics teachers; and offers a conceptual basis for designing instructional strategies that cultivate critical thinking dispositions in dealing with non-routine problems. By linking dispositional theory to observable problem-solving behavior, this study strengthens the theoretical and practical understanding of critical thinking dispositions in mathematics teacher preparation.

THEORETICAL SUPPORT

According to Ennis (1996), critical thinking disposition refers to an individual's tendency to act reflectively and rationally when facing situations demanding critical judgment, serving as the foundation that enables critical thinking skills to be consistently actualized (Facione, 2000; Perkins & Ritchhart, 2004; Ajzen, 1991; Halpern, 2014; Siegel, 2017). Decision quality is determined not only by cognitive abilities but also by dispositional readiness to think carefully, openly, and based on evidence (Stanovich & West, 2008; Kuhn, 1999). The literature identifies several characteristics of critical thinking disposition seeking clarity, prioritizing rationality, being systematic, and considering decision impact and accuracy (Facione, 2000; Nugroho, As'ari, & Sa'dijah, 2018; Paul & Elder, 2006; Willingham, 2008; Halpern, 2014) which ultimately converge on two core dispositions: truth-seeking and open-mindedness (Dwyer, Hogan, & Stewart, 2014; Ordem, 2017; Kuşçu & Erdoğan, 2024; Çelik & Özdemir, 2020; Yorgancı, 2016), viewed as minimal indicators signifying critical thinking disposition in action (Ennis, 1996; Facione, 2000; Kurniati & As'ari, 2021). Truth-seeking is the consistent tendency to obtain the best understanding based on evidence and reasoning, including willingness to question established assumptions (As'ari & Kurniati, 2021; Ennis, 1985; Facione, 2000; Kuhn, 1999; Perkins & Ritchhart, 2004), reflected in seeking clarity, evaluating arguments, using credible sources, maintaining relevance, and striving for accuracy in justification (Ennis, 1985; Halpern, 2014; Paul & Elder, 2006; Willingham, 2008; Siegel, 2017;

Stanovich & West, 2008) a habit of reflective thinking emphasizing verification and truth-testing before decisions (Choy & Oo, 2012; Dwyer *et al*., 2014; King & Kitchener, 1994; Kuhn, 1999; Ordem, 2017).

Open-mindedness is the tendency to consider various perspectives rationally and tolerate differences (As'ari & Kurniati, 2021; Ennis, 1996; Facione, 2000; Stanovich, 2016; Perkins & Ritchhart, 2004), enabling individuals to accept logical arguments even when they contradict personal views, prioritizing truth over subjective preferences (Ennis, 1985; Stanovich, 2016; Paul & Elder, 2006; Siegel, 2017; Halpern, 2014) and facilitating objective evaluation in problematic situations (King & Kitchener, 1994; Kuhn, 1999; Willingham, 2008; Dwyer *et al*., 2014; Ordem, 2017). In mathematics education, truth-seeking and open-mindedness become highly relevant when prospective teachers confront problems containing contradictory or incomplete information (Kurniati & As'ari, 2021; Putri *et al*., 2020; Yorgancı, 2016; Çelik & Özdemir, 2020; Kuşçu & Erdoğan, 2024). Contradictory problems contain ambiguous or conflicting information demanding clarification and consistency evaluation (As'ari *et al*., 2017; Hocking & Vernon, 2017; Ohlsson, 2012; Liu & Cheng, 2018; Walters & Bartlett, 2021), while incomplete problems lack sufficient information that must be identified and supplemented before determining a solution (Ohlsson, 2012; As'ari *et al*., 2017; Parker & Cohen, 2020; Singh & Gupta, 2023; Hart, 2019). Theoretically, such situations require activation of truth-seeking to examine validity and completeness of information, and open-mindedness to consider alternatives and accept logical corrections (Ennis, 1985; Facione, 2000; Dwyer et al., 2014; Kurniati & As'ari, 2021; Stanovich, 2016).

Although various studies have discussed critical thinking dispositions in general (Facione, 2000; Ennis, 1996; Halpern, 2014; Perkins & Ritchhart, 2004; Paul & Elder, 2006), research that specifically operationalizes the indicators of truth-seeking and open-mindedness in the context of solving contradictory and incomplete problems among prospective mathematics teachers remains limited (Kurniati & As'ari, 2021; Putri *et al*., 2020; Yorgancı, 2016; Çelik & Özdemir, 2020; Kuşçu & Erdoğan, 2024). Therefore, this study adapts indicators from Ennis (1985) to identify manifestations of these two dispositions before, during, and after the problem-solving process (Kurniati & As'ari, 2021; Dwyer *et al*., 2014; Facione, 2000; Ordem, 2017; Nugroho *et al*., 2018). The selection of these indicators is based on their relevance to the cognitive demands that arise in ambiguous and incomplete problem situations (King & Kitchener, 1994; Kuhn, 1999; Willingham, 2008; Liu & Cheng, 2018; Walters & Bartlett, 2021), ensuring that the theoretical framework directly informs the research design and the analysis of participants' behavior (Miles, Huberman, & Saldaña, 2014; Merriam & Tisdell, 2015; Patton, 2015).

METHOD

This study employed a qualitative descriptive-exploratory design to investigate truth-seeking and open-mindedness manifestations in prospective mathematics teachers' problem-solving processes, using a qualitative approach to explore in-depth behavioral tendencies when confronting cognitively demanding tasks rather than measuring disposition levels quantitatively (Merriam & Tisdell, 2015). The context involved mathematical problems containing contradictory and incomplete information, theoretically requiring activation of these dispositions (Ennis, 1985; Facione, 2000; Kurniati & As'ari, 2021). Fifteen seventh-semester mathematics education students at Al-Qolam University, Malang, were selected through purposive sampling based on microteaching completion, voluntary participation, and ability to articulate reasoning clearly (Patton, 2015). Data were collected through three complementary techniques: written tests comprising three non-routine problems (two contradictory, one incomplete) designed to trigger cognitive conflict (As'ari *et al.*, 2017), direct observation using behavioral indicators adapted from Ennis (1985), and semi-structured interviews to clarify reasoning and explore awareness of contradictions (Cohen, Manion, & Morrison, 2018; Kvale & Brinkmann, 2015), with all interviews audio-recorded and transcribed verbatim.

The instruments comprised a written test with three problems, an observation sheet documenting behavioral indicators, and an interview protocol, with content validity established through expert judgment involving a research supervisor, mathematics content expert, and mathematics education expert (Fraenkel, Wallen, & Hyun, 2012), followed by revisions to enhance clarity and refine descriptors. To strengthen methodological rigor, observation and interview data were coded using predefined indicators of truth-seeking (verifying information accuracy, identifying inconsistencies, revising illogical assumptions) and open-mindedness (considering alternative perspectives, discussing differing arguments, accepting logical corrections) (Kurniati & As'ari, 2021; Stanovich, 2016). Data analysis followed systematic qualitative principles adapted from Miles, Huberman, and Saldaña (2014), data familiarization, a priori coding, categorization into truth-seeking and open-mindedness, data synthesis, and interpretation linking behaviors to theoretical constructs. Methodological triangulation was applied by comparing findings across written work, observational notes, and interview transcripts (Lincoln & Guba, 1985), with inter-rater agreement assessed through a second coder independently analyzing a subset of data and discrepancies discussed until consensus.

RESULT AND DISCUSSION

Truth-Seeking and Open-Mindedness of Prospective Mathematics Teachers in Solving Problem 1

To examine how prospective mathematics teachers respond to logical inconsistencies, participants were presented with the following contradictory problem: Given $x, y, z \in R$, with $x^3 = 6$, $y^2 = -2$ and $z = 4$, determine the value of $x^3y^4 - z^2$. This item was intentionally designed as a contradictory problem because the condition $y^2 = -2$ is inconsistent within the real number system (As'ari et al., 2017; Hocking & Vernon, 2017; Ohlsson, 2012). Therefore, solving the problem meaningfully required participants to verify the validity of the given information before proceeding with algebraic manipulation (Ennis, 1985; Facione, 2000; Kurniati & As'ari, 2021).

Based on the coding results, five of the fifteen participants immediately concluded that the problem had no solution due to the condition $y^2 = -2$. Their written responses indicated direct rejection of the problem without further exploration (King & Kitchener, 1994; Kuhn, 1999; Willingham, 2008). In these cases, no evidence was found of attempts to (a) examine the implications of the contradiction more deeply, (b) reinterpret the domain assumption, or (c) discuss the inconsistency with peers or the instructor during the problem-solving session (Dwyer, Hogan, & Stewart, 2014; Paul & Elder, 2006; Halpern, 2014). From the perspective of the predefined indicators, these responses did not demonstrate the truth-seeking behaviors categorized as verification (TS1) or revision of illogical assumptions (TS2) (Ennis, 1985; Facione, 2000; Kurniati & As'ari, 2021). Specifically, participants did not investigate the consistency of the domain restriction beyond stating that $y^2 = -2$ has no solution in R (Choy & Oo, 2012; Nugroho, As'ari, & Sa'dijah, 2018; Perkins & Ritchhart, 2004). Furthermore, observational and interview data showed no indication of open-mindedness behaviors, such as considering alternative interpretations (OM1) or accepting logically justified revisions (OM2) (Stanovich, 2016; Siegel, 2017; Ordem, 2017). Instead, participants' reasoning remained confined to the initial contradiction without further reflective examination (King & Kitchener, 1994; Kuhn, 1999).

Analytically, the pattern reveals a tendency toward procedural termination once inconsistency is identified rather than deeper evaluative reasoning (Schoenfeld, 2017; Liu & Cheng, 2018; Walters & Bartlett, 2021), with absence of verification and exploratory dialogue indicating limited activation of truth-seeking and open-mindedness dispositions (Kurniati & As'ari, 2021; Dwyer *et al*., 2014; Facione, 2000). Participants treated contradictions as final conclusions without revising assumptions or seeking clarification (Paul & Elder, 2006; Willingham, 2008), demonstrating that early recognition of inconsistency did not extend into reflective or investigative reasoning (Perkins & Ritchhart, 2004; Kuhn, 1999; Halpern, 2014) a critical distinction because identifying an error does not indicate truth-seeking disposition unless followed by systematic verification and reconsideration of assumptions (Facione, 2000; Stanovich & West, 2008). Coding results showed five participants immediately concluded the problem had no solution due to $y^2 = -2$, with direct rejection and no evidence of deeper examination, reinterpretation of domain assumptions, or discussion with peers or instructor.

From the perspective of the predefined indicators, these responses did not demonstrate the truth-seeking behaviors categorized as verification (TS1) or revision of illogical assumptions (TS2). Specifically, participants did not investigate the consistency of the domain restriction beyond stating that $y^2 = -2$ has no solution in $\{R\}$. Furthermore, observational and interview data showed no indication of open-mindedness behaviors, such as considering alternative interpretations (OM1) or accepting logically justified revisions (OM2). Instead, participants' reasoning remained confined to the initial contradiction without further reflective examination. Analytically, this pattern suggests a tendency toward procedural termination once an inconsistency is identified, rather than engaging in deeper evaluative reasoning about the structure of the problem. The absence of verification and exploratory dialogue indicates limited activation of truth-seeking and open-mindedness dispositions in this context. Rather than revising assumptions (e.g., questioning whether the domain restriction should be reconsidered) or seeking clarification, participants treated the contradiction as a final conclusion.

Overall, the findings for Problem 1 reveal that a subset of prospective mathematics teachers demonstrated early recognition of inconsistency but did not extend this recognition into reflective or investigative reasoning. This distinction is important, as identifying an error does not necessarily indicate the presence of a truth-seeking disposition unless it is followed by systematic verification and reconsideration of assumptions.

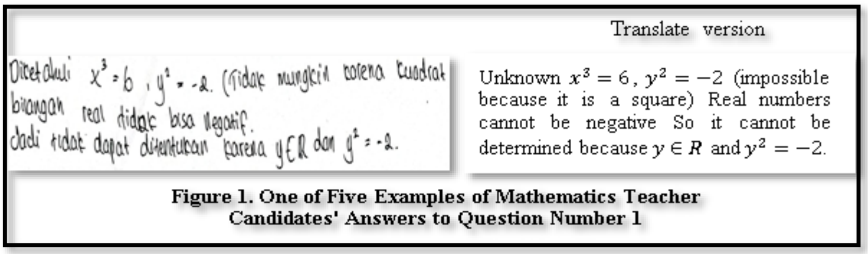

Figure 1. One of Five Examples of Mathematics Teache Candidates' Answer to Question Number 1

A contrasting response pattern emerged among the other eight prospective teachers. Rather than immediately attempting to solve the problem, these participants first engaged in a critical examination of the information provided in the task. This analytical process was directed toward evaluating the accuracy and consistency of the given data before determining an appropriate solution strategy (Facione, 2000; Kurniati & As'ari, 2021). After careful scrutiny, they recognized that the condition $y^2 = -2$ is impossible within the real number system, leading them to conclude that the problem has no solution. This verification behavior reflects the truth-seeking disposition, characterized by a tendency to examine the validity of information before proceeding with procedural computations (Choy & Oo, 2012; Dwyer, Hogan, & Stewart, 2014; Stanovich, 2016). The response patterns of these eight participants are illustrated in Figure 2.

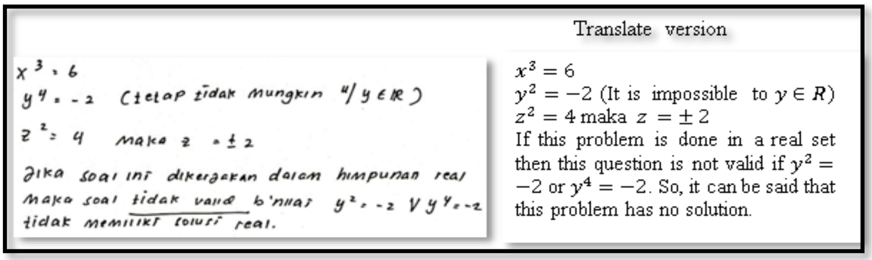

Figure 2. One of Eight Examples of Mathematics Teachers Candidates' Answer to Question Number 1

Two other prospective teachers followed a different path to recognizing that the first problem was unsolvable. Initially, they attempted direct substitution without prior analysis of the information. However, when substitution failed to yield a coherent answer, they did not stop there. Instead, they sought confirmation from the instructor, questioning whether the problem contained an error (Facione, 2000; Kurniati & As'ari, 2021). This verification effort reflects truth-seeking behavior (Dwyer et al., 2014; Stanovich, 2016).

Additionally, these participants engaged in discussions with colleagues, asserting that $y^2 = -2$ has no solution in the real number system. Their willingness to articulate and defend their reasoning while remaining open to dialogue demonstrates open-mindedness (Paul & Elder, 2006; Perkins & Ritchhart, 2004). Through verification and collaborative discourse, both participants exhibited integrated truth-seeking and open-mindedness dispositions (Facione, 2000; Kuhn, 1999). Figure 3 presents an example of their written responses.

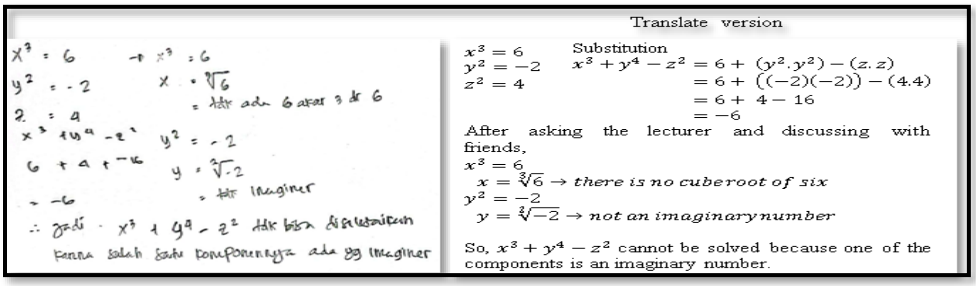

Figure 2. One of Two Examples of Mathematics Teachers Candidates' Answer to Question Number 1

Presented below is a revised analysis of the results for Problem 2, which has been strengthened through clearer theoretical alignment, minimized repetition, and deeper interpretive insight:

Truth-Seeking and Open-Mindedness of Prospective Mathematics Teachers in Solving Problem 2

The second problem required participants to determine the area of a triangle with side lengths of 3 cm, 6 cm, and 10 cm. This item was intentionally constructed as a contradictory problem because the given side lengths violate the triangle inequality theorem, which states that the sum of any two sides must be greater than the third side (i.e., $3 + 6 < 10$); therefore, a triangle cannot be formed (As'ari *et al*., 2017; Hocking & Vernon, 2017; Ohlsson, 2012). A meaningful solution therefore required participants to recognize this inconsistency before attempting to compute the area using standard formulas (Facione, 2000; Kurniati & As'ari, 2021).

Analysis of written responses, observational records, and interview transcripts revealed a consistent behavioral pattern among twelve of the fifteen participants. These participants proceeded directly to apply area formulas without first verifying whether the given side lengths could form a valid triangle (King & Kitchener, 1994; Kuhn, 1999; Willingham, 2008). Their written work showed immediate procedural engagement, indicating an assumption that the problem was mathematically valid and solvable (Schoenfeld, 2017; Liu & Cheng, 2018; Walters & Bartlett, 2021). From the perspective of the predefined indicators, these responses did not demonstrate truth-seeking behaviors categorized as verification of information (TS1). Participants did not examine the logical consistency of the given data before performing calculations (Choy & Oo, 2012; Dwyer, Hogan, & Stewart, 2014; Stanovich, 2016).

Even after being prompted by the instructor to re-examine their reasoning and discuss their answers, most of these participants maintained their initial assumptions (Paul & Elder, 2006; Perkins & Ritchhart, 2004; Kuhn, 1999). Observational data indicated limited engagement in argumentative evaluation or reconsideration of the problem's validity (Halpern, 2014; Siegel, 2017; Ordem, 2017). This pattern reflects what King and Kitchener (1994) describe as pre-reflective thinking, where individuals accept information at face value without critical examination.

Interview data provided further insight into this pattern. Several participants reported confusion in determining the position of the triangle's sides (e.g., base, height, hypotenuse), yet they did not question whether the triangle itself could exist (Parker & Cohen, 2020; Singh & Gupta, 2023; Hart, 2019). When the triangle inequality principle was explicitly discussed during the interview, participants acknowledged that the side lengths violated the necessary condition (Facione, 2000; Kurniati & As'ari, 2021). However, some stated that they had not considered verifying the condition because they assumed that the lecturer would only provide correct and solvable problems (Halpern, 2014; Siegel, 2017; Stanovich & West, 2008). This reasoning reflects what Perkins and Ritchhart (2004) term "dispositional failure" the gap between having the capacity to think critically and actually exercising that capacity in appropriate situations.

This reasoning reflects procedural compliance rather than evaluative inquiry (Facione, 2000; Perkins & Ritchhart, 2004), with participants showing limited initiative to independently verify information consistency (Kurniati & As'ari, 2021; Dwyer *et al*., 2014; Stanovich, 2016) and accepting logical explanations reactively rather than through self-initiated exploration or peer discussion (Paul & Elder, 2006; Kuhn, 1999; Willingham, 2008). Overall, Problem 2 findings indicate that most participants relied on implicit trust in authority rather than critical verification (Facione, 2000; Kurniati & As'ari, 2021), demonstrating that recognition of mathematical procedures does not necessarily activate truth-seeking and open-mindedness dispositions (Dwyer *et al*., 2014; Halpern, 2014; Willingham, 2008). The absence of early verification and independent reconsideration highlights a gap between procedural competence and dispositional critical engagement (King & Kitchener, 1994; Kuhn, 1999; Perkins & Ritchhart, 2004), aligning with research showing students struggle to transfer critical thinking dispositions to novel problem contexts despite possessing relevant procedural knowledge (Liu & Cheng, 2018; Walters & Bartlett, 2021).

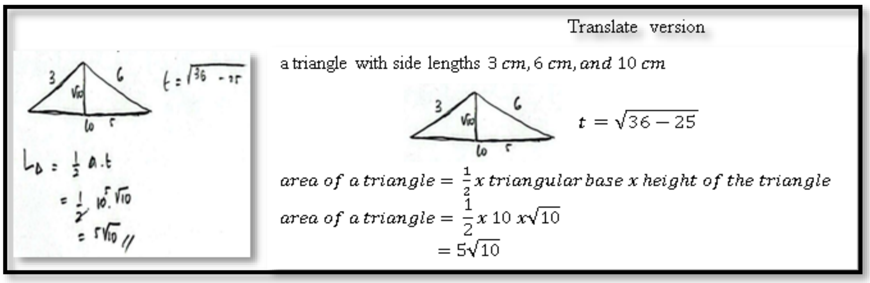

Figure 4. One of twelve Examples of answers given by prospective mathematics to question number 2

The behavioral tendencies of the 12 prospective mathematics teachers differed from those of the other three prospective teachers. These three prospective teachers showed tendencies that differed from the 12 subjects in the previous study. They investigated the truth at the beginning, when they were asked question number 2. An example of the answers given by the three prospective teachers who were the subjects of the study is presented in Figure 5.

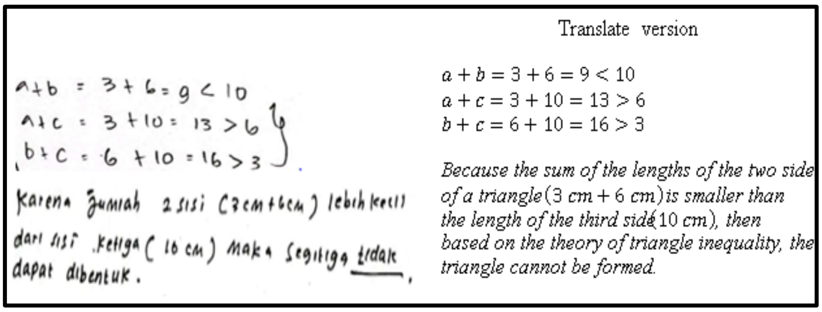

Figure 5. One of three Examples of answers given by prospective mathematics to question number 2

Based on the analysis of Figure 5 and corresponding video recordings, three of fifteen participants demonstrated truth-seeking behaviors by examining the logical consistency of the given side lengths before procedural calculations, identifying that 3 cm + 6 cm was not greater than 10 cm violating the triangle inequality theorem and concluding the problem was mathematically invalid through explicit reasoning and reference to established mathematical principles, indicating verification (TS1) and logical justification (TS2). Furthermore, these participants sought confirmation from the lecturer, reflecting open-mindedness through willingness to discuss their reasoning and consider responses grounded in logical argumentation. Overall, these three participants illustrated a consistent pattern of investigating information accuracy prior to solution attempts and accepting evidence-based alternative viewpoints, providing empirical evidence of both truth-seeking and open-mindedness dispositions in contradictory mathematical problem contexts.

Truth-Seeking and Open-Mindedness of Prospective Mathematics Teachers in Solving Problem 3

The third problem required participants to draw the graph of the equation 2x+y=122x+y=12. This item was intentionally categorized as an incomplete problem because no explicit domain restrictions or additional contextual conditions were provided (As'ari *et al*., 2017; Ohlsson, 2012; Hocking & Vernon, 2017). The task therefore required participants to examine underlying assumptions, particularly regarding the domain of xx and yy, before proceeding with graphical representation (Facione, 2000; Kurniati & As'ari, 2021). Problems of this type are designed to assess whether individuals recognize the need to question implicit assumptions rather than automatically applying standard procedures (King & Kitchener, 1994; Kuhn, 1999; Willingham, 2008).

Procedural Compliance without Verification of Assumptions

Analysis of written responses, observational data, and interview transcripts revealed a consistent behavioral pattern across all fifteen participants. Every participant immediately transformed the equation into slope–intercept form and constructed the corresponding straight-line graph without questioning the domain or considering alternative interpretations (Schoenfeld, 2017; Liu & Cheng, 2018; Walters & Bartlett, 2021). Their written work showed procedural fluency; however, no written or verbal evidence indicated prior verification of implicit assumptions (Choy & Oo, 2012; Dwyer, Hogan, & Stewart, 2014; Stanovich, 2016). This pattern reflects what Perkins and Ritchhart (2004) describe as the gap between cognitive capacity and dispositional execution the ability to perform procedures does not guarantee the inclination to critically examine underlying conditions.

From the perspective of the predefined indicators, none of the participants demonstrated truth-seeking behaviors categorized as verification of conditions (TS1) before solving the problem (Facione, 2000; Kurniati & As'ari, 2021). Specifically, they did not examine whether the absence of domain specification might influence the nature of the graph or the interpretation of the equation (Paul & Elder, 2006; Halpern, 2014; Siegel, 2017). This finding aligns with research by Kuhn (1999) and King and Kitchener (1994), who found that learners often fail to recognize ambiguity in problem statements when contextual cues are absent.

Insights from Interview Data

During interviews, participants stated that when no domain is explicitly mentioned, it is standard to assume that variables belong to the set of real numbers (Parker & Cohen, 2020; Singh & Gupta, 2023; Hart, 2019). This assumption was described as a conventional agreement in mathematics instruction a response that reflects what Perkins and Ritchhart (2004) term "enculturated practice" rather than reflective judgment. During lecturer-mediated discussion, participants maintained this position and justified it using established classroom conventions (Ordem, 2017; Stanovich & West, 2008; Willingham, 2008). While they were able to articulate logical reasons for their assumption, there was no observable attempt to explore alternative possibilities (e.g., restricted domains such as integers, natural numbers, or discrete sets) (Liu & Cheng, 2018; Walters & Bartlett, 2021; Schoenfeld, 2017). Thus, open-mindedness behaviors such as considering multiple interpretations (OM1) were not evident (Facione, 2000; Paul & Elder, 2006). Acceptance of the real-number assumption occurred without prior evaluative comparison of alternatives (Kuhn, 1999; King & Kitchener, 1994; Perkins & Ritchhart, 2004). This pattern reflects what Halpern (2014) describes as "mindless application" the tendency to apply learned procedures without critical reflection on their appropriateness in specific contexts.

Theoretical Implications

Analytically, this pattern reflects reliance on implicit institutional norms rather than reflective examination of problem completeness (Facione, 2000; Kurniati & As'ari, 2021). Although participants' reasoning was procedurally correct under standard real-number assumptions, the absence of explicit verification indicates limited activation of truth-seeking in the context of incomplete information (Dwyer *et al*., 2014; Stanovich, 2016; Choy & Oo, 2012). Similarly, open-mindedness was not demonstrated through exploration of alternative conditions but rather through adherence to established conventions (Paul & Elder, 2006; Siegel, 2017; Ordem, 2017). This finding is consistent with research by Liu and Cheng (2018) and Walters and Bartlett (2021), who found that students rarely question implicit assumptions in problem statements unless explicitly prompted to do so.

Overall, the findings from Problem 3 suggest that when confronted with incomplete problems, participants tended to default to conventional assumptions without engaging in explicit evaluative inquiry (King & Kitchener, 1994; Kuhn, 1999; Willingham, 2008). This tendency highlights a distinction between procedural competence and dispositional critical engagement, particularly in situations that require examination of implicit mathematical conditions (Perkins & Ritchhart, 2004; Halpern, 2014; Stanovich & West, 2008). The absence of verification and exploration behaviors underscores the need for instructional interventions that explicitly cultivate truth-seeking and open-mindedness dispositions in mathematics teacher education (Kurniati & As'ari, 2021; Facione, 2000).

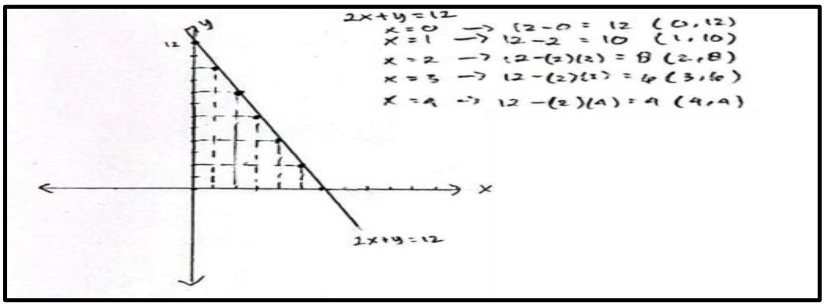

Figure 6. One of 15 Examples of answers given by prospective mathematics to question number 3

The findings reveal that most prospective mathematics teachers did not consistently demonstrate truth-seeking and open-mindedness dispositions when solving contradictory and incomplete problems, with observable behaviors being predominantly procedural rather than evaluative (King & Kitchener, 1994; Kuhn, 1999; Willingham, 2008) engaging directly in computational manipulation without first verifying logical consistency, validity, or completeness of information (Schoenfeld, 2017; Liu & Cheng, 2018; Walters & Bartlett, 2021). Truth-seeking behaviors such as investigating assumption accuracy (TS1) and revising illogical premises (TS2) were demonstrated only by a small subset (Facione, 2000; Kurniati & As'ari, 2021), while open-mindedness behaviors such as considering alternative interpretations (OM1) and accepting logically justified revisions (OM2) were limited and occurred reactively rather than through self-initiated inquiry (Paul & Elder, 2006; Stanovich, 2016; Perkins & Ritchhart, 2004).

The Role of Institutional Trust and Academic Norms

One notable pattern emerging from interview data is the strong reliance on institutional trust. Many participants assumed that problems provided by lecturers must be correct and solvable, which reduced their perceived need to verify information independently (Halpern, 2014; Siegel, 2017; Ordem, 2017). This tendency suggests that dispositional limitations may not stem solely from cognitive deficits but from habituated academic norms that prioritize procedural completion over evaluative questioning (Perkins & Ritchhart, 2004; Kuhn, 1999; King & Kitchener, 1994). Such a pattern reflects a compliance-oriented problem-solving culture rather than a critical-inquiry orientation (Paul & Elder, 2006; Willingham, 2008; Dwyer, Hogan, & Stewart, 2014).

Alignment with Previous Research

These findings align with previous studies conducted by As'ari, Mahmudi, and Nuerlaelah (2017) and Kurniati and Zayyadi (2018), which reported that prospective mathematics teachers in Indonesia often exhibit limited critical thinking tendencies. The present study extends these findings by providing process-based qualitative evidence that illustrates how these dispositional limitations manifest in real-time problem-solving situations (Schoenfeld, 2017; Powell, Francisco, & Maher, 2003; Derry *et al*., 2010). Furthermore, the results corroborate Akgun and Duruk (2016), who found that truth-seeking and open-mindedness are frequently underdeveloped dispositions among teacher candidates. However, this study contributes additional insight by demonstrating that the absence of these dispositions becomes particularly visible when individuals encounter ambiguous, contradictory, or incomplete mathematical tasks (Hocking & Vernon, 2017; Ohlsson, 2012; Liu & Cheng, 2018).

Theoretically, the findings reinforce the distinction between procedural competence and dispositional critical engagement (Perkins & Ritchhart, 2004; Facione, 2000). Participants were generally capable of applying formulas and algebraic transformations correctly; however, procedural fluency did not automatically translate into evaluative inquiry (Stanovich & West, 2008; Halpern, 2014; Willingham, 2008). This supports the view that critical thinking disposition is not an inherent byproduct of mathematical knowledge but requires deliberate cultivation (Kurniati & As'ari, 2021; Dwyer *et al*., 2014; Paul & Elder, 2006).

Comparison with As'ari et al. (2017) and Ennis (1996)

The results of research conducted by As'ari et al. (2017) on truth-seeking behavior tendencies of prospective mathematics teachers identified three categories: (1) not investigating the truth before solving the problem (non-critical thinker and unreflective thinker), (2) investigating the truth after solving the problem in an illogical and incomplete manner (emergent critical thinker and challenged thinker), and (3) investigating the truth while solving the problem (developing critical thinker and beginning thinker). The present findings predominantly reflect the first category, with most participants falling into the non-critical or unreflective thinker classification.

These findings appear to stand in tension with Ennis's theoretical framework, which conceptualizes critical thinking as a dispositional orientation toward verification and reasoned evaluation, yet prospective teachers did not consistently exhibit these characteristics when confronted with contradictory problems (Kurniati & As'ari, 2021; Facione, 2000; Stanovich, 2016). This discrepancy may reflect contextual factors within mathematics teacher education procedural instructional emphasis, assessment prioritizing correct answers over evaluative reasoning, and strong reliance on lecturer authority which normalize assumption-based problem solving (Schoenfeld, 2017; Liu & Cheng, 2018; Walters & Bartlett, 2021; Paul & Elder, 2006; Perkins & Ritchhart, 2004; Kuhn, 1999), allowing students to develop technical proficiency without cultivating the disposition to interrogate information validity (Halpern, 2014; Willingham, 2008; Siegel, 2017). Thus, rather than contradicting Ennis's framework, these findings highlight a gap between normative theoretical standards of critical thinking and actual dispositional development fostered in current instructional contexts (King & Kitchener, 1994; Kuhn, 1999; Dwyer *et al*., 2014).

Interpretation through Ajzen's Theory of Planned Behavior

The absence of truth-seeking behavior observed in this study can be interpreted through Ajzen's (1991) Theory of Planned Behavior, which explains non-truth-seeking tendencies not as mere cognitive limitations but as products of three interrelated components shaped by motivational and social influences (Ajzen, 1991; Perkins & Ritchhart, 2004; Halpern, 2014). Participants' limited truth-seeking and open-mindedness stem from: (1) attitude perceiving contradictory problems as routine procedural tasks requiring task-completion mindset without verification (Ajzen, 1991; Fishbein & Ajzen, 2010; Schoenfeld, 2017; Liu & Cheng, 2018; Walters & Bartlett, 2021; Perkins & Ritchhart, 2004; Kuhn, 1999; Willingham, 2008; Choy & Oo, 2012; Dwyer *et al*., 2014; Stanovich, 2016; Dündar & Yaman, 2015); (2) subjective norms institutional trust from instructional environments assuming lecturer problems are correct, reducing independent verification (Ajzen, 1991; Fishbein & Ajzen, 2010; Halpern, 2014; Siegel, 2017; Ordem, 2017; Paul & Elder, 2006; Perkins & Ritchhart, 2004; Kuhn, 1999; Darby & Rashid, 2017) despite detectable inconsistencies (King & Kitchener, 1994; Kuhn, 1999; Willingham, 2008); and (3) perceived behavioral control viewing contradictory problems as inherently difficult, creating uncertainty beyond familiar procedures and inhibiting truth-seeking due to doubted capacity for cognitive complexity (Ajzen, 1991; Pajares, 1996; Zimmerman, 2000; Schoenfeld, 2017; Liu & Cheng, 2018; Walters & Bartlett, 2021; Dündar & Yaman, 2015; Parker & Cohen, 2020; Singh & Gupta, 2023; Hart, 2019).

Importantly, these three components did not operate independently (Ajzen, 1991; Fishbein & Ajzen, 2010). A procedural attitude toward mathematics, reinforced by classroom norms that prioritize correct answers, combined with low perceived control over ambiguous tasks, created conditions under which truth-seeking dispositions were unlikely to emerge (Perkins & Ritchhart, 2004; Kuhn, 1999; Halpern, 2014). Thus, the present findings extend Ajzen's framework by illustrating how dispositional critical thinking in mathematical contexts may be constrained not only by individual willingness but also by entrenched pedagogical cultures (Schoenfeld, 2017; Liu & Cheng, 2018; Walters & Bartlett, 2021).

Practical Implications for Mathematics Teacher Education

Based on the foregoing analysis, instructional designs that explicitly cultivate truth-seeking and open-mindedness are imperative in mathematics teacher education (Ennis, 1996; Facione, 2000; Kurniati & As'ari, 2021), as prospective teachers tend to rely on procedural execution, institutional trust, and implicit assumptions when confronted with contradictory problems (King & Kitchener, 1994; Kuhn, 1999; Willingham, 2008), indicating that critical thinking dispositions do not automatically emerge from content mastery but require deliberate pedagogical intervention (Perkins & Ritchhart, 2004; Halpern, 2014; Dwyer *et al*., 2014). Infusion and immersion learning (Darby & Rashid, 2017; Ennis, 1989) offer relevant alternatives infusion integrates explicit instruction on verifying assumptions (truth-seeking) and considering alternative interpretations (open-mindedness) within regular mathematics lessons (Ennis, 1989; Facione, 2000; Paul & Elder, 2006), systematically incorporating tasks with incomplete or conflicting information that require students to identify, question, and justify underlying premises before calculations (Kurniati & As'ari, 2021; Liu & Cheng, 2018; Walters & Bartlett, 2021), directly addressing the observed deficit in verification behaviors (TS1) (Choy & Oo, 2012; Dwyer *et al*., 2014; Stanovich, 2016).

Meanwhile, immersion learning embeds students in learning environments where evaluative reasoning becomes a habitual practice rather than an occasional activity (Ennis, 1989; Perkins & Ritchhart, 2004; Kuhn, 1999). Through sustained exposure to non-routine, ambiguous, and discussion-based problem-solving contexts, students are encouraged to engage in argumentative dialogue, defend claims with logical evidence, and revise positions when confronted with counterarguments (Paul & Elder, 2006; Kuhn, 1999; King & Kitchener, 1994). Such environments can foster open-mindedness (OM1 and OM2) by normalizing intellectual risk-taking and reflective reconsideration behaviors that were minimally observed in this study (Facione, 2000; Stanovich, 2016; Siegel, 2017).

Senar (2014) further suggests that these approaches can be integrated with both traditional and alternative problem-solving models. However, their effectiveness depends on contextual implementation (Schoenfeld, 2017; Liu & Cheng, 2018; Walters & Bartlett, 2021). In instructional settings where assessment systems prioritize procedural correctness over justificatory reasoning, efforts to cultivate truth-seeking may encounter resistance (Perkins & Ritchhart, 2004; Kuhn, 1999; Willingham, 2008). Similarly, strong hierarchical classroom norms may inhibit students from questioning given information (Halpern, 2014; Siegel, 2017; Ordem, 2017). Therefore, pedagogical reform must be accompanied by adjustments in assessment design, classroom discourse practices, and lecturer modeling of evaluative inquiry (Paul & Elder, 2006; Facione, 2000; Ennis, 1996).

Limitations and Future Research Directions

Nevertheless, this study has several limitations. The sample was limited to one institution and involved a relatively small number of participants, which restricts generalizability (Merriam & Tisdell, 2015; Patton, 2015). In addition, the findings are context-dependent and based on qualitative interpretation, although triangulation was employed to enhance credibility (Lincoln & Guba, 1985; Flick, 2018). Future research could involve cross-institutional comparisons or mixed-method approaches to examine the relationship between dispositional tendencies and instructional interventions more comprehensively (Miles *et al*., 2014; Cohen *et al*., 2018). Longitudinal studies could also investigate whether and how truth-seeking and open-mindedness dispositions develop over the course of teacher preparation programs (King & Kitchener, 1994; Kuhn, 1999; Perkins & Ritchhart, 2004).

CONCLUSION

This study investigated the manifestation of truth-seeking and open-mindedness dispositions among prospective mathematics teachers when solving problems containing contradictory and incomplete information. The findings reveal a consistent pattern across three problem contexts: the majority of participants demonstrated procedural competence but lacked the dispositional orientation to critically evaluate the validity, consistency, and completeness of given information before attempting solutions. Truth-seeking behaviors verifying assumptions (TS1) and revising illogical premises (TS2) were exhibited by only a small subset of participants, while open-mindedness behaviors considering alternative interpretations (OM1) and accepting logically justified revisions (OM2) were largely reactive rather than self-initiated. Notably, participants' reliance on institutional trust assuming that lecturer-provided problems must be correct and solvable emerged as a significant barrier to activating critical thinking dispositions, reflecting a compliance-oriented problem-solving culture rather than a critical-inquiry orientation. Through the lens of Ajzen's (1991) Theory of Planned Behavior, these non-truth-seeking tendencies can be understood as products of interrelated attitudinal, normative, and control beliefs rather than mere cognitive deficits, extending Ennis's (1996) framework by demonstrating how contextual factors mediate the activation of critical thinking dispositions.

The study contributes theoretically by providing empirical evidence supporting the distinction between procedural competence and dispositional critical engagement (Perkins & Ritchhart, 2004), and methodologically by operationalizing observable indicators of truth-seeking and open-mindedness that enable systematic identification of dispositional manifestations. Practically, the findings underscore the imperative for instructional designs that explicitly cultivate these dispositions through infusion and immersion learning models (Ennis, 1989; Darby & Rashid, 2017), accompanied by systemic changes in assessment practices and classroom discourse norms. Strengthening truth-seeking and open-mindedness is essential for developing mathematics teachers who are not only technically competent but also critically reflective in evaluating mathematical information. Future research should employ cross-institutional comparisons and longitudinal designs to examine how these dispositions develop over time and respond to targeted interventions, preparing future educators to navigate the complexities of 21st-century mathematics classrooms with both procedural proficiency and critical evaluative capacity

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