



Linking mathematical literacy to teaching competence through creative thinking: evidence from prospective mathematics teachers

Nur Asrawati*
STKIP YPUP Makassar,
INDONESIA

Andi Tenriawaru
STKIP YPUP Makassar,
INDONESIA

Sirwanti
Universitas Muhammadiyah Bone,
INDONESIA

Muhammad Nurhusain
STKIP YPUP Makassar,
INDONESIA

Article Info

Article history:

Received: June 05, 2026

Revised: July 30, 2026

Accepted: Augst 20, 2026

Keywords:

Creative Thinking;
Mathematical Literacy;
Teaching competence;
Prospective Mathematics
Teachers; PLS-SEM.

Abstract

Background: Teaching competence among prospective mathematics teachers requires not only mathematical understanding but also the ability to transform such knowledge into flexible and context-responsive pedagogical decisions. Creative thinking may provide a critical pathway connecting mathematical literacy with teaching competence.

Aims: This study investigated the mediating role of creative thinking in the relationship between mathematical literacy and teaching competence among prospective mathematics teachers.

Method: An explanatory cross-sectional survey involved 149 sixth-semester prospective mathematics teachers. Data were collected through five-point Likert-scale measures and analyzed using partial least squares structural equation modeling (PLS-SEM) with 3,000 bootstrap resamples.

Results: Mathematical literacy was strongly associated with creative thinking ($\beta = 0.907, p < .001$), which was significantly associated with teaching competence ($\beta = 0.762, p < .001$). The direct relationship between mathematical literacy and teaching competence was nonsignificant ($\beta = 0.178, p = .077$), whereas the indirect relationship through creative thinking was significant ($\beta = 0.691, 95\% \text{ CI } [0.523, 0.851]$). The model demonstrated substantial explanatory and predictive capacity ($R^2 = 0.823\text{--}0.858; Q^2 > .80; \text{SRMR} = 0.052$).

Conclusion: Creative thinking represents an important statistical pathway linking mathematical literacy with teaching competence. Given the cross-sectional and self-reported data, these findings indicate predictive associations rather than causal relationships.

To cite this article: Asrawati, N., Tenriawaru, A., Sirwanti. & Nurhusain, M. (2026). Linking mathematical literacy to teaching competence through creative thinking: evidence from prospective mathematics teachers. *Journal of Advanced Sciences and Mathematics Education*, 6(3), 569-585.

INTRODUCTION

Teaching competence among prospective mathematics teachers has become a central concern in mathematics teacher education because contemporary instruction requires teachers to mobilize mathematical knowledge, pedagogical judgment, and adaptive decision-making rather than merely reproduce disciplinary procedures (Kaiser et al., 2025; Y. Zhang et al., 2025). This concern is particularly salient in Indonesia, where PISA 2022 continues to document substantial challenges in students' mathematical performance and where the creative-thinking assessment also indicates a limited proportion of students reaching the highest levels of performance. Although large-scale assessment outcomes cannot be attributed solely to teachers, recent research on mathematics teaching competence and professional learning suggests that the quality of instruction depends substantially on teachers' capacity to interpret classroom situations, respond to learners' thinking,

*Corresponding author:

Nur Asrawati, STKIP YPUP Makassar, Indonesia
nurasrawatiypup@gmail.com ✉

and convert knowledge into productive instructional action (König et al., 2022; Shure et al., 2025). Accordingly, prospective teacher preparation needs to emphasize not only what future teachers know mathematically but also how they reason with that knowledge when constructing explanations, selecting representations, designing tasks, and responding to emerging learning difficulties (Dindyal et al., 2021; Weyers et al., 2024).

Within this professional context, mathematical literacy provides an important cognitive foundation because it involves recognizing mathematically relevant information, formulating mathematical representations, employing appropriate concepts and procedures, interpreting results, and evaluating solutions in relation to authentic contexts (Cevikbas et al., 2022; Geiger et al., 2022). For prospective mathematics teachers, these processes are pedagogically consequential because teaching requires them to move beyond obtaining correct answers toward reconstructing mathematical meaning in forms that can be understood, questioned, and extended by learners (Hwang & Han, 2025; Quarder et al., 2025). Recent modeling research further indicates that mathematically rich tasks require coordination between contextual interpretation, representation, quantitative reasoning, and validation, thereby making mathematical literacy a dynamic form of reasoning rather than a static collection of procedures (Krawitz et al., 2025; Nguyen & Tran, 2025). At the same time, studies of prospective teachers' engagement with modeling show that strong conceptual understanding does not automatically ensure the ability to design authentic tasks, anticipate students' approaches, or select pedagogically productive interventions (Cevikbas et al., 2025; Ledezma et al., 2024). For this reason, examining creative thinking as a mediating mechanism is theoretically warranted: mathematical literacy may provide the cognitive resources for interpreting and structuring mathematical situations, whereas creative thinking may determine how those resources are reorganized into adaptive pedagogical decisions.

This distinction between understanding mathematics and transforming that understanding into teachable forms highlights creative thinking as a potentially important mechanism in prospective teacher development (Lu & Kaiser, 2022; Y. Zhang et al., 2025). In mathematics education, creativity is commonly associated with fluency, flexibility, originality, and elaboration, yet recent research increasingly treats creativity as a process of generating, comparing, and refining mathematically meaningful alternatives under contextual and disciplinary constraints (Leikin et al., 2025). Evidence from creativity-directed mathematics teacher education indicates that prospective teachers can develop stronger capacities to design open tasks, generate multiple solution pathways, and use problem posing to produce mathematically worthwhile learning opportunities (Baumanns & Rott, 2024; Bicer et al., 2022). Related work on problem-creation processes also shows that creativity in teacher education is not equivalent to unconstrained novelty because mathematically creative products must remain solvable, conceptually coherent, contextually plausible, and pedagogically usable (Elgrably & Leikin, 2021; Sánchez et al., 2022).

Creative thinking is particularly relevant to teaching competence because classroom instruction is inherently adaptive and requires teachers to generate alternatives when initial explanations, representations, or task structures do not support learners as intended (Rotem & Ayalon, 2024; Scheiner et al., 2024). Research on mathematics teacher noticing demonstrates that competent instruction depends on attending to significant features of students' thinking, interpreting the mathematical meaning of their responses, and selecting actions that sustain or extend productive reasoning (Santagata et al., 2021; van Es & Sherin, 2021). Studies of prospective mathematics teachers likewise show that instructional visions and enacted responses may diverge, indicating that pedagogical competence requires more than possessing principles of good teaching; it requires the capacity to translate those principles into situated decisions (Osmanoglu & Girit-Yildiz, 2024; Stockero et al., 2022). This adaptive dimension is reinforced by evidence that making sense of student mathematical thinking involves both mathematical interpretation and in-the-moment pedagogical

judgment, processes that are central to the transformation of knowledge into responsive teaching practice.

The pedagogical relevance of creativity is also visible in the design of mathematical tasks and learning environments, where prospective teachers must coordinate mathematical validity, openness, cognitive demand, contextual relevance, and anticipated student responses (Ferrando et al., 2025). Problem posing has therefore been increasingly positioned as a professional practice through which future teachers learn to reinterpret curricular materials, create new mathematical opportunities, and evaluate the instructional affordances of tasks rather than reproduce textbook exercises (Burgos et al., 2025; Cai et al., 2026). Beyond task design, structured creative processes such as design thinking can strengthen prospective teachers' ability to produce more interactive and adaptive lesson plans, suggesting that creativity can be deliberately directed toward pedagogical design rather than treated as an incidental personal characteristic (Albay & Eisma, 2025; Liu, 2022). Micro-teaching and modeling-specific pedagogical learning similarly demonstrate that professional competence is strengthened when prospective teachers repeatedly design, enact, observe, analyze, and revise instruction using mathematically substantive tasks (Bozkurt & Yiğit Koyunkaya, 2022; Greefrath et al., 2022).

The transition from university coursework to the situated demands of teaching further illustrates why professional competence cannot be inferred from conceptual knowledge alone, because prospective teachers must learn to prepare mathematical ideas for instruction, interpret students' reasoning, and revise planned actions in response to classroom evidence (Scheiner et al., 2024). Research that foregrounds students' mathematical strengths and unconventional representations shows that prospective teachers need opportunities to recognize mathematically productive ideas even when those ideas differ from canonical forms, thereby requiring interpretive flexibility as well as disciplinary accuracy (Kalinec-Craig et al., 2021; Marmur & Zazkis, 2022). Practice-based and simulation-oriented approaches are consequently important because they allow prospective teachers to rehearse professional judgment in low-risk environments while confronting the ambiguity, multiplicity, and time-sensitive decision-making characteristic of classroom practice (Louie et al., 2021). Evidence on error handling and assessment practices also demonstrates that teaching competence depends on how teachers interpret incomplete or unexpected student work and use that information to make subsequent instructional decisions, reinforcing the need for flexible reasoning in addition to formal mathematical knowledge (Kaufmann et al., 2023).

Despite these advances, the literature still tends to examine mathematical literacy, mathematical creativity, modeling competence, teacher noticing, and teaching competence as related but largely separate strands, leaving the mechanism connecting mathematical understanding with pedagogical enactment insufficiently specified (Y. Zhang et al., 2025). Reviews of teacher competence indicate that professional knowledge is related to instructional quality, but they also emphasize that situated processes of interpretation and decision-making are required before knowledge becomes observable teaching performance (Kaiser et al., 2025; Lu & Kaiser, 2022). In parallel, studies of mathematical modeling and digital pedagogical knowledge show that prospective teachers may possess substantial conceptual resources while still needing structured opportunities to transform those resources into instructional tasks, representations, and interventions (Quarder et al., 2025). This unresolved transition provides the rationale for examining creative thinking not merely as an additional desirable outcome, but as a mediating process through which mathematical literacy may become pedagogically actionable (Hwang & Han, 2025).

Despite increasing scholarly attention to mathematical literacy, creative thinking, and teaching competence, the relationships among these constructs remain relatively fragmented within the existing literature. Recent studies have demonstrated a close connection between mathematical literacy and creative thinking, suggesting that mathematical understanding and prior mathematical

knowledge provide important cognitive resources for generating flexible, original, and meaningful mathematical ideas (Aditya & Hakiem, 2026; Djam'an et al., 2021; Xu et al., 2025). Parallel research on prospective mathematics teachers has emphasized the importance of mathematical literacy, mathematical competence, and professional teaching competence in preparing future teachers to address authentic instructional demands (Llanos-Lagos et al., 2025; Tinh et al., 2021; Videla et al., 2026), while another strand of research has highlighted creative thinking, task design, and creativity-oriented learning as important components of prospective teachers' professional development and instructional preparation (Murtafiah et al., 2026; Shodiq et al., 2025; Sujadi et al., 2025). Research examining teacher competencies and creativity further suggests that creative capacities are increasingly recognized as relevant to effective teaching and twenty-first-century teacher preparation (Cojorn & Sonsupap, 2024; Jingwen et al., 2026). Nevertheless, these strands have predominantly examined the constructs separately, through pairwise relationships, or within specific instructional and professional-development interventions, leaving the mechanism through which mathematical literacy may be associated with teaching competence insufficiently explained. In particular, limited empirical attention has been directed toward testing creative thinking as a mediating pathway between mathematical literacy and teaching competence among prospective mathematics teachers. The present study addresses this gap by integrating mathematical literacy as a cognitive resource, creative thinking as a mediating pathway, and teaching competence as a pedagogical outcome within a unified structural model, thereby extending previous research toward a more integrated literacy-creativity-competence framework.

Based on this gap, the present study examines a structural model in which creative thinking is positioned as a mediating mechanism between mathematical literacy and teaching competence among prospective mathematics teachers. Specifically, the study investigates whether mathematical literacy is positively associated with creative thinking, whether creative thinking is positively associated with teaching competence, whether mathematical literacy retains a direct association with teaching competence when creative thinking is incorporated into the model, and whether creative thinking mediates the relationship between mathematical literacy and teaching competence. The novelty of the study lies in integrating these three constructs within a single structural model that positions creative thinking not merely as an additional competence, but as a mechanism that may explain how mathematical literacy is translated into teaching competence. By testing this model among prospective mathematics teachers in Indonesia, the study aims to provide empirical support for a literacy-creativity-competence framework and to extend understanding of the process through which mathematical knowledge is transformed into adaptive pedagogical decision-making. Consistent with the cross-sectional design and the use of self-reported data, the relationships examined in this study are interpreted as predictive-associative rather than as definitive evidence of causality.

LITERATURE REVIEW

Mathematical literacy is increasingly conceptualized as the capacity to use mathematics to interpret, represent, analyze, and evaluate situations rather than as the simple reproduction of formal procedures, and contemporary modeling research reinforces this emphasis on contextual reasoning, representation, and validation (Cevikbas et al., 2022; Geiger et al., 2022). In prospective teacher education, this orientation is especially important because future teachers must operate simultaneously as mathematical problem solvers and as designers of learning opportunities that help students connect mathematical structures with real situations (Ledezma et al., 2024). Quantitative reasoning has been shown to support changes in preservice teachers' modeling competence, while international reviews of modeling tasks emphasize authenticity, openness, and interpretive demand

as central features of mathematically literate activity (Krawitz et al., 2025; Nguyen & Tran, 2025). These findings imply that mathematical literacy should be developed through experiences that require prospective teachers to formulate assumptions, compare representations, justify modeling choices, and evaluate the reasonableness of solutions in ways that can later inform instructional design (Greefrath et al., 2022; Quader et al., 2025).

The literature on mathematical creativity provides a complementary account of how such conceptual resources may become generative, because creativity involves producing multiple mathematically meaningful possibilities and refining them in response to disciplinary and contextual constraints (Lu & Kaiser, 2022; van Es & Sherin, 2021). Research with prospective mathematics teachers indicates that modeling and problem posing are particularly productive contexts for creativity because their openness permits multiple goals, strategies, representations, and products while still requiring mathematical coherence (Leikin et al., 2025). Creativity-directed preparation can also influence the quality of the tasks prospective teachers design and their willingness to use such tasks instructionally, suggesting that creative performance is shaped by opportunities to learn rather than being a fixed personal disposition. From this perspective, mathematical creativity becomes pedagogically relevant when prospective teachers can turn fluency, flexibility, originality, and elaboration into examples, prompts, alternative explanations, representations, and open-ended tasks that support different pathways of student reasoning (Elgrably & Leikin, 2021; Sánchez et al., 2022).

Teaching competence, however, requires more than the possession of mathematical and creative resources because professional performance emerges through the interpretation of situated classroom information and the selection of appropriate responses (König et al., 2022; Weyers et al., 2024). Teacher-noticing research consistently shows that competence includes attending to relevant events, interpreting students' mathematical thinking, and deciding how to respond, thereby positioning situation-specific skills between professional knowledge and observable instruction (Rotem & Ayalon, 2024; Scheiner et al., 2022). Video-based and practice-oriented teacher education has been shown to strengthen these interpretive processes by giving prospective teachers repeated opportunities to analyze classroom episodes and connect professional knowledge with instructional choices (Santagata et al., 2021; van Es & Sherin, 2021). Related studies further demonstrate that the quality of teachers' responses to student thinking depends on whether they can recognize the mathematical potential of students' ideas and preserve that potential through appropriate instructional moves (Osmanoglu & Girit-Yildiz, 2024; Stockero et al., 2022).

The situated nature of mathematics teaching also means that professional competence depends on prospective teachers' ability to work productively with ambiguity, partial understanding, and non-standard forms of student reasoning rather than only with anticipated textbook responses (Kalinec-Craig et al., 2021; Marmur & Zazkis, 2022). Conceptual work on preparing mathematics for teaching further suggests that mathematical ideas must be reorganized in relation to representations, examples, anticipated interpretations, and instructional purposes before they can function effectively in classroom practice. Practice environments, including simulations and structured professional experimentation, are valuable because they make decision processes visible and revisable, allowing prospective teachers to connect knowledge with action while receiving feedback on the consequences of their instructional choices (Louie et al., 2021). Research on teachers' handling of errors and assessment practices similarly indicates that instructional competence is revealed through the quality of interpretation and follow-up action, particularly when student responses require teachers to depart from predetermined procedures and make mathematically defensible adjustments in real time.

The relationship between mathematical literacy and creative thinking is theoretically plausible because mathematically literate activity requires individuals to identify relevant

structures, shift among representations, interpret consequences, and evaluate alternative pathways, all of which provide cognitive conditions for flexible and generative mathematical reasoning (Ferrando et al., 2025). Problem posing makes this relationship particularly visible because creating mathematically meaningful problems requires both deep understanding of content and the capacity to generate new structures or contexts from that understanding. The relationship between creative thinking and teaching competence is equally plausible because responsive instruction requires teachers to adapt explanations, modify tasks, and construct alternative representations while maintaining mathematical integrity and cognitive demand. Evidence from micro-teaching and problem-based professional learning suggests that such adaptive capacity develops when prospective teachers are repeatedly required to enact, evaluate, and redesign instruction rather than merely describe pedagogical principles abstractly.

A direct association between mathematical literacy and teaching competence can also be expected because teachers need connected mathematical understanding to analyze students' strategies, judge the validity of solutions, select representations, and design tasks that preserve important conceptual relationships. Nevertheless, recent competence research cautions that content-related knowledge influences instruction through situation-specific processes and that the transition from knowing to doing is neither automatic nor uniform across prospective teachers. Practice-based studies similarly show that prospective teachers benefit when opportunities to learn deliberately connect mathematical analysis with enactment, reflection, and revision, thereby narrowing the gap between declarative understanding and situated pedagogical action (Marbán et al., 2021). These findings support a model in which mathematical literacy supplies conceptual resources, whereas creative thinking helps reorganize those resources into instructional possibilities that can subsequently be selected and enacted as teaching competence (Dindyal et al., 2021).

The proposed mediating role of creative thinking therefore represents more than a statistical arrangement among three desirable competencies because it specifies a theoretically interpretable sequence from mathematical understanding to generative transformation and then to pedagogical enactment. Under this account, mathematical literacy enables prospective teachers to recognize structures, construct models, interpret solutions, and evaluate validity, whereas creative thinking enables them to generate alternative representations, tasks, explanations, and responses that make those mathematical resources pedagogically usable (Pratama & Yelken, 2024). Teaching competence emerges when these alternatives are evaluated and transformed into context-sensitive instructional decisions, a view consistent with contemporary research that frames professional competence as the mobilization of knowledge through situation-specific perception, interpretation, and action. Based on this synthesis, the present study positions creative thinking as a transformational mechanism in the relationship between mathematical literacy and teaching competence. The mediation examined in this study is interpreted as an indirect predictive association rather than as definitive causal evidence, consistent with the cross-sectional design.

METHOD

Research Design

This study employed a quantitative approach using an explanatory survey design. The design was selected because the study sought to examine the structural relationships among mathematical literacy, creative thinking, and teaching competence and to assess the mediating role of creative thinking within a single analytical model. Data were collected at one point in time; therefore, the study was cross-sectional. The proposed model positioned mathematical literacy as the exogenous construct, creative thinking as the mediating construct, and teaching competence as the endogenous construct. Partial least squares structural equation modeling (PLS-SEM) was employed because the

analysis focused on estimating relationships among latent constructs, assessing an indirect effect, and evaluating the explanatory and predictive capacity of the proposed model. Given the cross-sectional and self-reported nature of the data, the estimated structural relationships were interpreted as predictive-associative rather than as definitive causal effects.

Participant

The participants were sixth-semester prospective mathematics teachers enrolled in a mathematics education program. A total of 150 questionnaire responses were initially collected. During data screening, one response was excluded because it was blank and did not contain valid responses within the required 1–5 scoring range. Consequently, 149 complete responses were retained for the final analysis. Of the 149 participants, 109 (73.2%) were female, and 40 (26.8%) were male. With respect to prior teaching experience, 26 participants (17.4%) reported having teaching experience, whereas 123 participants (82.6%) reported no previous teaching experience. The participants were selected at the sixth-semester level because they had completed relevant mathematics education coursework and had sufficient exposure to both mathematical content and pedagogical learning to provide informed responses regarding the constructs examined in the study.

Table 1. Participant Characteristics

Characteristic	Category	n	%
Gender	Female	109	73.2
	Male	40	26.8
Teaching experience	Yes	26	17.4
	No	123	82.6
Data status	Valid responses	149	100.0

Population and Sampling

The study population comprised sixth-semester prospective mathematics teachers enrolled in the mathematics education program in which the research was conducted. Participants were required to meet two inclusion criteria: they had to be registered as sixth-semester students and had to have completed relevant mathematics education coursework. These criteria were established to ensure that participants had sufficient academic exposure to mathematical content and pedagogical concepts relevant to the variables under investigation. The sample was selected using convenience sampling based on the availability and accessibility of prospective mathematics teachers who satisfied the inclusion criteria and were available during the data-collection period. This sampling procedure was consistent with the survey-based nature of the study. It enabled the researchers to obtain data from respondents who represented the intended stage of prospective teacher preparation. The final sample consisted of 149 valid cases. The sample size was considered adequate for the PLS-SEM analysis because the proposed structural model was relatively parsimonious, with a maximum of two predictors directed toward an endogenous construct. The adequacy of the sample was also considered in relation to the study's emphasis on structural path estimation, mediation analysis, and predictive explanation rather than covariance-based model reproduction. Nevertheless, because a non-probability sampling technique was employed, generalization of the findings beyond the study context should be undertaken cautiously.

Instrumentation

Data were collected using a self-administered questionnaire consisting of 15 items distributed across three reflective latent constructs: mathematical literacy, creative thinking, and teaching competence. All items were rated using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Higher item responses therefore reflected stronger perceived levels of the corresponding construct. For structural analysis, the individual indicators were modeled reflectively within their respective latent constructs rather than treated merely as isolated observed

scores. Mathematical literacy was represented by five indicators addressing the ability to understand a mathematical problem, formulate a mathematical model, employ relevant mathematical concepts, interpret results, and evaluate the plausibility of an answer. Creative thinking was represented by five indicators covering fluency, flexibility, originality, elaboration, and open-ended problem solving. Teaching competence was represented by five indicators addressing instructional planning, content mastery, teaching strategies, classroom communication, and learning assessment. The questionnaire assessed participants' perceptions of their own capabilities rather than their objectively observed performance. Accordingly, the resulting scores were interpreted as measures of perceived mathematical literacy, perceived creative thinking, and perceived teaching competence. This distinction was maintained throughout the study to avoid treating self-reported competence as equivalent to directly observed performance.

Instruments and Data Collection

The instrument comprised three multi-item reflective measures, each consisting of five indicators. The content structure of the instrument is presented in Table 2.

Table 2. Instrument Blueprint

Construct	Code	Indicator / Item Content
Mathematical literacy	LM1	Understanding a mathematical problem
	LM2	Formulating a mathematical model
	LM3	Using relevant mathematical concepts
	LM4	Interpreting mathematical results
	LM5	Evaluating the plausibility of an answer
Creative thinking	BK1	Fluency
	BK2	Flexibility
	BK3	Originality
	BK4	Elaboration
	BK5	Open-ended problem solving
Teaching competence	KM1	Instructional planning
	KM2	Content mastery
	KM3	Teaching strategies
	KM4	Classroom communication
	KM5	Learning assessment

Because the constructs were operationalized as reflective measures, their psychometric properties were evaluated through indicator reliability, internal consistency reliability, convergent validity, and discriminant validity. Indicator reliability was examined through outer loadings. All retained indicators demonstrated loadings above 0.70, ranging from 0.873 to 0.935 for mathematical literacy, from 0.951 to 0.973 for creative thinking, and from 0.943 to 0.965 for teaching competence. Internal consistency was assessed using Cronbach's alpha and composite reliability. Mathematical literacy obtained a Cronbach's alpha of 0.946 and composite reliability of 0.960; creative thinking obtained values of 0.979 and 0.984, respectively; and teaching competence obtained values of 0.976 and 0.981. Convergent validity was evaluated using average variance extracted (AVE), which reached 0.829 for mathematical literacy, 0.925 for creative thinking, and 0.913 for teaching competence. All AVE values therefore exceeded the recommended minimum criterion of 0.50. Discriminant validity was examined using both the Fornell–Larcker criterion and the heterotrait–monotrait ratio (HTMT). The square root of the AVE for each construct exceeded its corresponding inter-construct correlations. HTMT values were 0.944 for mathematical literacy and creative thinking, 0.905 for mathematical literacy and teaching competence, and 0.945 for creative thinking and teaching competence. Bootstrapped confidence intervals for the HTMT estimates did not include 1.00, supporting the empirical distinction among the three constructs. However, the relatively high values indicated substantial conceptual proximity and warranted cautious interpretation.

Table 3. Psychometric Properties of the Instrument

Construct	Cronbach's Alpha	Composite Reliability	AVE	Loading Range
Mathematical literacy	0.946	0.960	0.829	0.873–0.935
Creative thinking	0.979	0.984	0.925	0.951–0.973
Teaching competence	0.976	0.981	0.913	0.943–0.965

Research Procedure

Data collection was conducted during a single measurement period in accordance with the cross-sectional survey design. Prospective participants were first identified according to the predetermined inclusion criteria. The questionnaire containing the 15 indicators of mathematical literacy, creative thinking, and teaching competence was then administered using the same five-point response format for all respondents. After questionnaire administration, the returned responses were screened for completeness and admissible scoring. A total of 150 responses were obtained. One blank response was identified during the screening stage and excluded because it did not satisfy the required response range. The remaining 149 cases contained complete scores within the 1–5 scale and were retained for analysis. The analytical procedure was conducted sequentially. Data screening and respondent profiling were completed first, followed by evaluation of the measurement model. Potential collinearity and common method variance were subsequently examined before testing the structural relationships and mediation effect. Finally, the explanatory power, predictive relevance, effect sizes, and overall approximate model fit were evaluated. Because all constructs were measured from the same respondents during the same measurement period, common method variance was explicitly considered during model assessment. The present manuscript does not report the specific calendar dates or duration of questionnaire administration. Accordingly, no precise data-collection dates are stated here; these should be added if such information is available in the original research documentation.

Data Analysis

Data analysis was conducted using partial least squares structural equation modeling (PLS-SEM) and proceeded through a series of sequential stages. First, preliminary data screening was undertaken to examine response completeness, the admissible 1–5 scoring range, and participant characteristics. The measurement model was then evaluated before interpretation of the structural relationships. The reflective measurement model was assessed using outer loadings, Cronbach's alpha, composite reliability, and average variance extracted. Convergent validity was considered satisfactory when AVE exceeded 0.50, and indicator loadings reached acceptable levels. Discriminant validity was examined using the Fornell–Larcker criterion and HTMT. The square root of AVE was compared with inter-construct correlations, while HTMT estimates and their bootstrap confidence intervals were examined to assess whether the constructs demonstrated sufficient empirical distinction (Almarashdi & Jarrah, 2022; Mursidik et al., 2015).

Potential collinearity and common method bias were subsequently examined because all three constructs were collected from the same respondents through the same questionnaire format during a single measurement period. Inner variance inflation factors (VIFs) were examined to identify potential collinearity among predictor constructs. Harman's single-factor test was also conducted as a diagnostic assessment of potential common method variance. These diagnostics were treated as indicators requiring interpretive caution rather than as definitive evidence for or against method bias. The structural model was assessed using bootstrapping with 3,000 resamples and 95% confidence intervals. The hypothesized relationships were evaluated using standardized path coefficients (β), standard errors, t-statistics, p-values, and bootstrap confidence intervals. The direct paths from mathematical literacy to creative thinking, from creative thinking to teaching competence, and from mathematical literacy to teaching competence were evaluated together with

the specific indirect effect from mathematical literacy to teaching competence through creative thinking. Mediation was determined based on the statistical significance and confidence interval of the indirect effect while simultaneously considering the corresponding direct effect.

Finally, model quality was evaluated using the coefficient of determination (R^2), predictive relevance (Q^2), effect size (f^2), and composite standardized root mean square residual (SRMR). R^2 was used to assess the proportion of variance explained in the endogenous constructs, Q^2 was used to examine predictive relevance, and f^2 was used to determine the relative contribution of individual predictor constructs. Composite SRMR was reported as an approximate measure of model fit. Because the research design was cross-sectional and all major constructs were based on self-reported perceptions, the structural coefficients and mediation effects were interpreted as predictive associations rather than definitive evidence of causal relationships.

RESULTS AND DISCUSSION

Results

Descriptive Statistics and Measurement Model

The construct means were in the medium-to-high range. All constructs demonstrated high internal consistency and composite reliability. AVE values exceeded 0.50, confirming convergent validity, and all indicator outer loadings were above 0.70. However, the very high reliability values warrant caution, as they may reflect conceptual proximity among constructs and strong item homogeneity

Table 3. Descriptive Statistics, Reliability, and Convergent Validity

Construct	Mean	SD	Alpha	CR	AVE	Loading range
Mathematical literacy	3.568	0.864	0.946	0.960	0.829	0.873–0.935
Creative thinking	3.510	0.970	0.979	0.984	0.925	0.951–0.973
Teaching competence	3.541	0.966	0.976	0.981	0.913	0.943–0.965

Note. SD = standard deviation; Alpha = Cronbach's alpha; CR = composite reliability; AVE = average variance extracted

Table 4. Indicator Outer Loadings

Construct	Indicator	Outer loading	Decision
Mathematical literacy	LM1	0.925	Valid
Mathematical literacy	LM2	0.873	Valid
Mathematical literacy	LM3	0.935	Valid
Mathematical literacy	LM4	0.903	Valid
Mathematical literacy	LM5	0.916	Valid
Creative thinking	BK1	0.951	Valid
Creative thinking	BK2	0.972	Valid
Creative thinking	BK3	0.960	Valid
Creative thinking	BK4	0.952	Valid
Creative thinking	BK5	0.973	Valid
Teaching competence	KM1	0.943	Valid
Teaching competence	KM2	0.964	Valid
Teaching competence	KM3	0.965	Valid
Teaching competence	KM4	0.960	Valid
Teaching competence	KM5	0.945	Valid

Discriminant Validity and Model Diagnostics

The Fornell–Larcker criterion was met, as the square root of AVE for each construct exceeded its correlations with other constructs. The HTMT assessment further indicated that the bootstrap confidence intervals did not include 1.00. However, the HTMT values for mathematical literacy–

creative thinking and creative thinking-teaching competence approached the 0.95 threshold. This result suggests that, although the constructs are statistically distinguishable, their empirical interdependence is substantial and requires cautious interpretation.

Table 5. Discriminant Validity Based on the Fornell–Larcker Criterion

Construct	$\sqrt{\text{AVE}}$	LM	BK	KM
Mathematical literacy	0.911	—	0.907	0.869
Creative thinking	0.962	0.907	—	0.923
Teaching competence	0.956	0.869	0.923	—

Note. LM = mathematical literacy; BK = creative thinking; KM = teaching competence.

Table 6. Discriminant Validity Based on HTMT

Construct pair	HTMT	95% bootstrap CI	Interpretation
Mathematical literacy – Creative thinking	0.944	[0.920, 0.963]	Accepted; close to the 0.95 threshold
Mathematical literacy – Teaching competence	0.905	[0.838, 0.950]	Accepted; close to the 0.95 threshold
Creative thinking – Teaching competence	0.945	[0.913, 0.969]	Accepted; close to the 0.95 threshold

Table 7. Diagnostics for Method Bias, Collinearity, and Model Fit

Diagnostic indicator	Value	Interpretation
Harman single-factor variance	83.19%	Indicates strong potential common method variance
Inner VIF LM and BK → KM	5.635	High collinearity; the direct path must be interpreted conservatively
Composite SRMR	0.052	Adequate model fit (< .08)
Invalid/deleted data	1	One blank response was excluded from the analysis

Harman's single-factor test showed that the first factor explained 83.19% of the variance; therefore, the possibility of common method variance cannot be ignored. The inner VIF of 5.635 also indicates high collinearity between mathematical literacy and creative thinking when predicting teaching competence. These diagnostics do not invalidate the model, but they reinforce the need to interpret the results as predictive associations rather than causal inferences.

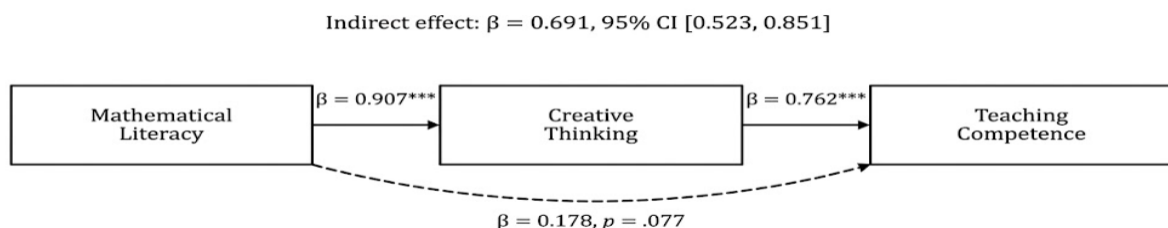


Figure 1. Structural Model of the Relationships among Mathematical Literacy, Creative Thinking, and Teaching Competence

Table 8. Structural Path Result

Path	β	SE	t	p	95% CI	Decision
Mathematical literacy → Creative thinking	0.907	0.017	54.343	< .001	[0.870, 0.935]	Significant
Creative thinking → Teaching competence	0.762	0.092	8.312	< .001	[0.578, 0.942]	Significant
Mathematical literacy → Teaching competence	0.178	0.100	1.771	.077	[-0.020, 0.374]	Not significant
Indirect effect LM → BK → KM	0.691	0.083	8.373	< .001	[0.523, 0.851]	Significant

Note. CI = 95% bootstrap confidence interval.

Mathematical literacy had a very strong effect on creative thinking. Creative thinking also had a significant effect on teaching competence. In contrast, the direct effect of mathematical literacy on teaching competence was not significant after creative thinking was included in the model. The indirect effect of mathematical literacy on teaching competence, via creative thinking, was significant. This pattern indicates statistically significant full mediation, with the caveat that this conclusion should be interpreted with caution because the data are not longitudinal.

Table 9. R^2 , Q^2 , and f^2 Effect Size

Endogenous construct	Predictor	R^2	Q^2	f^2	Effect category
Creative thinking	Mathematical literacy	0.823	0.820	4.635	Very large
Teaching competence	Mathematical literacy	0.858	0.850	0.040	Small
Teaching competence	Creative thinking	0.858	0.850	0.727	Large

The R^2 values indicate that mathematical literacy accounts for a substantial proportion of the variance in creative thinking. In contrast, mathematical literacy and creative thinking together explain a significant proportion of the variance in teaching competence. The Q^2 values for both endogenous constructs were well above zero, confirming the model's predictive relevance. The f^2 effect sizes demonstrate that the contribution of mathematical literacy to creative thinking was very large, the contribution of creative thinking to teaching competence was large, and the direct contribution of mathematical literacy to teaching competence was small when creative thinking was considered.

Discussion

The first finding demonstrates that mathematical literacy is a very strong predictor of creative thinking. Theoretically, this result is explained by the inclusion of abilities such as reading the structure of a problem, identifying relevant information, formulating a model, selecting concepts, interpreting solutions, and evaluating the plausibility of answers within mathematical literacy. This combination of abilities provides the cognitive foundation necessary for creativity. Mathematical creativity emerges not from fragmented knowledge but from the capacity to connect concepts, shift representations, recognize patterns, and generate alternative strategies. This finding aligns with studies on mathematical creativity, problem posing, and modeling, which emphasize the importance of understanding problem structure in generating varied and meaningful solutions (Bicer et al., 2020; W. Zhang et al., 2024). For prospective teachers, mathematical literacy also serves as a foundation for constructing pedagogical representations and appropriately utilizing learning technologies. Therefore, mathematical literacy should be regarded as a cognitive prerequisite for instructional creativity rather than solely as an individual academic achievement.

Creative thinking emerged as the primary predictor of teaching competence. This finding reinforces the argument that teaching competence cannot be developed solely through content mastery. Prospective teachers with strong creative thinking skills are better equipped to design contextual examples, develop open-ended questions, employ alternative strategies, construct representations, and adapt explanations to students' needs. Within the pedagogical content knowledge framework, creativity serves as the mechanism that transforms mathematical knowledge into representations and instructional strategies accessible to students. This finding is also consistent with research on open-ended tasks, representation-based activities, and STEAM approaches, which demonstrate that idea elaboration, representational manipulation, and personal articulation enhance prospective teachers' ability to develop more adaptive learning designs (Scheiner & Amador, 2025). Creative thinking enables prospective teachers not only to solve problems but also to explain, compare, modify, and evaluate teaching strategies. These processes directly correspond to dimensions of teaching competence, including planning, classroom communication, teaching techniques, and learning assessment.

The direct effect of mathematical literacy on teaching competence was not significant when creative thinking was included in the model. This result indicates that mathematical literacy does not automatically lead to teaching competence. A prospective teacher who understands mathematical problems may still lack the ability to design accessible explanations, select alternative representations, or develop activities that promote student engagement. Mathematical literacy must be mediated by creative processes to be transformed into adaptable pedagogical actions. Methodologically, this result should be considered alongside the high HTMT and inner VIF values. The empirical proximity between mathematical literacy and creative thinking may diminish literacy's unique contribution to predicting teaching competence. Therefore, the full mediation observed in this study does not imply that mathematical literacy is unimportant. Rather, it indicates that its contribution to teaching competence primarily operates through creative enactment. This interpretation aligns with PLS-SEM principles, which emphasize the combined evaluation of construct validity, effect sizes, predictive relevance, and collinearity (Widodo et al., 2023).

Implications

Theoretically, this study reinforces the literacy-creativity-competence model as an explanatory framework for developing teaching competence among prospective mathematics teachers. The model demonstrates that mathematical literacy serves as a cognitive prerequisite, while creative thinking acts as a transformational mechanism linking literacy to pedagogical competence. This contribution extends previous research, which has often examined literacy or creativity in isolation. In practice, teacher education programs should integrate contextualized literacy tasks with creative activities. Implementation may involve problem posing, open-ended tasks, scenario-based microteaching, collaborative lesson design, reflection on alternative strategies, and technology integration to visualize mathematical concepts. These activities should aim not only to improve literacy outcomes but also to prepare prospective teachers to transform mathematical knowledge into adaptable instructional decisions.

Limitations and Suggestions for Future Research

This study has several limitations. First, the cross-sectional design does not permit examination of the development of teaching competence over time. Second, all variables were measured through self-report, which increases the likelihood of common method variance. Third, HTMT values and inter-construct correlations near the threshold indicate a need to refine the items to more clearly distinguish mathematical literacy, creative thinking, and teaching competence. Fourth, teaching competence was not verified through microteaching observation, performance rubrics, lesson-planning artifacts, or expert evaluation. Future research should employ longitudinal, experimental, or mixed-method designs with data triangulation. Self-report measures should be supplemented with performance-based mathematical literacy tests, mathematical creativity tasks, microteaching videos, observation rubrics, and reflective interviews. Subsequent studies could also include variables such as self-efficacy, reflective practice, pedagogical content knowledge, technological pedagogical reasoning, or digital mathematical literacy to broaden the model of the development of teaching competence among prospective mathematics teachers.

CONCLUSION

This study examined a structural model in which creative thinking serves as a mediating mechanism between mathematical literacy and teaching competence among prospective mathematics teachers. The results indicate that mathematical literacy strongly influences creative thinking, and that creative thinking, in turn, significantly affects teaching competence. In contrast, the direct effect of mathematical literacy on teaching competence was not significant when creative

thinking was included in the model. The significant indirect effect suggests that creative thinking is the primary pathway linking mathematical literacy and teaching competence. Theoretically, this study clarifies the role of creative thinking as a transformational mechanism within the literacy-creativity-competence model. In practice, the findings suggest that prospective mathematics teacher education programs should design learning experiences that integrate mathematical literacy with creative activities, including open-ended tasks, problem posing, contextualized learning design, microteaching, and pedagogical reflection. In this way, enhancing mathematical literacy becomes more meaningful when it is directed toward developing prospective teachers' capacity for adaptive pedagogical decision-making.

AUTHOR CONTRIBUTIONS STATEMENT

Nur Asrawati contributed to the conceptualization, research design, instrument development, data collection, data analysis, interpretation of the findings, and preparation of the original manuscript. Andi Tenriawaru contributed to the conceptualization, research methodology, validation, interpretation of the findings, and review and editing of the manuscript. Sirwanti contributed to the theoretical framework, research methodology, interpretation of the results, and critical revision of the manuscript. Muhammad Nurhusain contributed to data analysis, interpretation of the findings, visualization, and review and editing of the manuscript. All authors contributed to the intellectual development of the study, critically reviewed the manuscript, and approved the final version for publication.

REFERENCES

- Aditya, A. Y., & Hakiem, M. R. (2026). Developing creative thinking skills through strengthening prior knowledge in mathematical literacy. *Journal of Creativity*, 100126. <https://doi.org/10.1016/j.yjoc.2026.100126>
- Albay, E. M., & Eisma, D. V. (2025). Using design thinking for developing pre-service teachers' creativity in designing teaching plans to promote interactive learning in mathematics. *Learning and Instruction*, 96, 102070. <https://doi.org/10.1016/j.learninstruc.2024.102070>
- Almarashdi, H. S., & Jarrah, A. M. (2022). The impact of a proposed mathematics enrichment program on UAE students' mathematical literacy based on the PISA framework. *Sustainability*, 14(18). <https://doi.org/10.3390/su141811259>
- Baumanns, L., & Rott, B. (2024). Problem-posing tasks and their influence on pre-service teachers' creative problem-posing performance and self-efficacy. *The Journal of Mathematical Behavior*, 73, 101130. <https://doi.org/10.1016/j.jmathb.2024.101130>
- Bicer, A., Bicer, A., Perihan, C., & Lee, Y. (2022). Pre-service teachers' preparations for designing and implementing creativity-directed mathematical tasks and instructional practices. *Mathematics Education Research Journal*, 34(3), 491–521. <https://doi.org/10.1007/s13394-022-00409-x>
- Bicer, A., Lee, Y., Perihan, C., Capraro, M. M., & Capraro, R. M. (2020). Considering mathematical creative self-efficacy with problem posing as a measure of mathematical creativity. *Educational Studies in Mathematics*, 105(3), 457–485. <https://doi.org/10.1007/s10649-020-09995-8>
- Bozkurt, G., & Yiğit Koyunkaya, M. (2022). Supporting prospective mathematics teachers' planning and teaching technology-based tasks in the context of a practicum course. *Teaching and Teacher Education*, 119, 103830. <https://doi.org/10.1016/j.tate.2022.103830>
- Burgos, M., Tizón-Escamilla, N., & Chaverri, J. (2025). A model for problem creation: Implications for teacher training. *Mathematics Education Research Journal*, 37(1), 55–84. <https://doi.org/10.1007/s13394-023-00482-w>
- Cai, J., Liu, Q., Xu, B., & Hwang, S. (2026). Posing problems confidently: Task-specific self-efficacy and self-evaluation in mathematical problem posing. *Educational Studies in Mathematics*, 122(3), 537–561. <https://doi.org/10.1007/s10649-026-10484-7>

- Cevikbas, M., Kaiser, G., & Schukajlow, S. (2022). A systematic literature review of the current discussion on mathematical modelling competencies: State-of-the-art developments in conceptualizing, measuring, and fostering. *Educational Studies in Mathematics*, 109(2), 205–236. <https://doi.org/10.1007/s10649-021-10104-6>
- Cevikbas, M., Mießeler, D., & Kaiser, G. (2025). Pre-service mathematics teachers' experiences and insights into the benefits and challenges of using explanatory videos in flipped modelling education. *ZDM – Mathematics Education*, 57(2), 245–258. <https://doi.org/10.1007/s11858-025-01650-x>
- Cojorn, K., & Sonsupap, K. (2024). A collaborative professional development and its impact on teachers' ability to foster higher order thinking. *Journal of Education and Learning (EduLearn)*, 18(2), 561–569. <https://doi.org/10.11591/edulearn.v18i2.21182>
- Dindyal, J., Schack, E. O., Choy, B. H., & Sherin, M. G. (2021). Exploring the terrains of mathematics teacher noticing. *ZDM – Mathematics Education*, 53(1), 1–16. <https://doi.org/10.1007/s11858-021-01249-y>
- Djam'an, N., Bernard, & Sahid. (2021). Developing students' creativity in building city mathematics through project based learning. *Journal of Physics: Conference Series*, 1899(1), 012147. <https://doi.org/10.1088/1742-6596/1899/1/012147>
- Elgrably, H., & Leikin, R. (2021). Creativity as a function of problem-solving expertise: Posing new problems through investigations. *ZDM – Mathematics Education*, 53(4), 891–904. <https://doi.org/10.1007/s11858-021-01228-3>
- Ferrando, I., Barquero, B., & Segura, C. (2025). Does training matter? Effect of training strategies on how pre-service teachers pose and assess modelling problems. *ZDM – Mathematics Education*, 57(2), 275–288. <https://doi.org/10.1007/s11858-025-01658-3>
- Geiger, V., Galbraith, P., Niss, M., & Delzoppo, C. (2022). Developing a task design and implementation framework for fostering mathematical modelling competencies. *Educational Studies in Mathematics*, 109(2), 313–336. <https://doi.org/10.1007/s10649-021-10039-y>
- Greefrath, G., Siller, H.-S., Klock, H., & Wess, R. (2022). Pre-service secondary teachers' pedagogical content knowledge for the teaching of mathematical modelling. *Educational Studies in Mathematics*, 109(2), 383–407. <https://doi.org/10.1007/s10649-021-10038-z>
- Hwang, S., & Han, S. (2025). Pre-service mathematics teachers' competencies in designing mathematical modeling tasks. *Journal of Mathematics Teacher Education*, 28(3), 713–743. <https://doi.org/10.1007/s10857-025-09678-2>
- Jingwen, C., Hidayat, R., & Zulkifli, M. Z. bin H. @. (2026). Teachers' STEAM competencies for the 21st century: A systematic review. *Eurasia Journal of Mathematics, Science and Technology Education*, 22(7), em2868. <https://doi.org/10.29333/ejmste/18868>
- Kaiser, G., König, J., Krauss, S., Buchholtz, N., & Gruber, H. (2025). Are teacher expertise and teacher competence complementary or contradictory research paradigms? Reflections on a possible integration and first conceptualizations. *ZDM – Mathematics Education*, 57(6), 1077–1092. <https://doi.org/10.1007/s11858-025-01743-7>
- Kalinec-Craig, C. A., Bannister, N., Bowen, D., Jacques, L. A., & Crespo, S. (2021). "It was smart when:" Supporting prospective teachers' noticing of students' mathematical strengths. *Journal of Mathematics Teacher Education*, 24(4), 375–398. <https://doi.org/10.1007/s10857-020-09464-2>
- Kaufmann, O. T., Larsson, M., & Ryve, A. (2023). Teachers' error-handling practices within and across lesson phases in the mathematics classroom. *International Journal of Science and Mathematics Education*, 21(4), 1289–1314. <https://doi.org/10.1007/s10763-022-10294-2>
- König, J., Santagata, R., Scheiner, T., Adleff, A.-K., Yang, X., & Kaiser, G. (2022). Teacher noticing: A systematic literature review of conceptualizations, research designs, and findings on learning to notice. *Educational Research Review*, 36, 100453. <https://doi.org/10.1016/j.edurev.2022.100453>
- Krawitz, J., Schukajlow, S., Yang, X., & Geiger, V. (2025). A systematic review of international perspectives on mathematical modelling: Modelling goals and task characteristics. *ZDM – Mathematics Education*, 57(2), 193–212. <https://doi.org/10.1007/s11858-025-01683-2>
- Ledezma, C., Breda, A., & Font, V. (2024). Prospective teachers' reflections on the inclusion of mathematical modelling during the transition period between the face-to-face and virtual

- teaching contexts. *International Journal of Science and Mathematics Education*, 22(5), 1057–1081. <https://doi.org/10.1007/s10763-023-10412-8>
- Leikin, R., Boriskovsky, M., Ovodenko, R., & Miskin, M. (2025). Problem posing or mathematical modeling? The process of expert instructional design. *ZDM – Mathematics Education*, 57(2), 333–350. <https://doi.org/10.1007/s11858-025-01668-1>
- Liu, X. S. (2022). Bias correction for eta squared in one-way ANOVA. *Methodology*, 18(1), 44–57. <https://doi.org/10.5964/meth.7745>
- Llanos-Lagos, E. A., Pino-Fan, L. R., Lugo-Armenta, J. G., Parra-Urrea, Y. E., Hernández, J. L. Z., & Núñez, R. E. U. (2025). Mathematical competencies of prospective teachers when teaching confidence intervals in a microteaching context. *Eurasia Journal of Mathematics, Science and Technology Education*, 21(9), em2701. <https://doi.org/10.29333/ejmste/16845>
- Louie, N., Adiredja, A. P., & Jessup, N. (2021). Teacher noticing from a sociopolitical perspective: The FAIR framework for anti-deficit noticing. *ZDM – Mathematics Education*, 53(1), 95–107. <https://doi.org/10.1007/s11858-021-01229-2>
- Lu, X., & Kaiser, G. (2022). Can mathematical modelling work as a creativity-demanding activity? An empirical study in China. *ZDM – Mathematics Education*, 54(1), 67–81. <https://doi.org/10.1007/s11858-021-01316-4>
- Marbán, J. M., Palacios, A., & Maroto, A. (2021). Enjoyment of teaching mathematics among pre-service teachers. *Mathematics Education Research Journal*, 33(3), 613–629. <https://doi.org/10.1007/s13394-020-00341-y>
- Marmur, O., & Zazkis, R. (2022). Productive ambiguity in unconventional representations: "What the fraction is going on?". *Journal of Mathematics Teacher Education*, 25(6), 637–665. <https://doi.org/10.1007/s10857-021-09510-7>
- Mursidik, E. S. M., Samsiyah, N., & Rudyanto, H. E. (2015). Kemampuan berpikir kreatif dalam memecahkan masalah Matematika open-ended ditinjau dari tingkat kemampuan matematika siswa sekolah dasar: Creative thinking ability in solving open-ended mathematical problems judging from the mathematics ability level of elementary school students. *Pedagogia: Jurnal Pendidikan*, 4(1), 23–33. <https://doi.org/10.21070/pedagogia.v4i1.69>
- Murtafiah, W., Lukitasari, M., & Lestari, N. D. S. (2026). Empowering future mathematics educators: Designing e-IBCA learning model to enhance decision-making skills. *Infinity Journal*, 15(1), 89–114. <https://doi.org/10.22460/infinity.v15i1.p89-114>
- Nguyen, A. T. T., & Tran, D. (2025). Quantitative reasoning as a lens to examine changes in modelling competencies of secondary preservice teachers. *Mathematics Education Research Journal*, 37(1), 27–54. <https://doi.org/10.1007/s13394-023-00481-x>
- Osmanoglu, A., & Girit-Yildiz, D. (2024). Examining how prospective mathematics teachers' instructional visions align with their responding practices through scripting tasks. *International Journal of Science and Mathematics Education*, 22(7), 1411–1434. <https://doi.org/10.1007/s10763-023-10435-1>
- Pratama, R. A., & Yelken, T. Y. (2024). Effectiveness of ethnomathematics-based learning on students' mathematical literacy: A meta-analysis study. *Discover Education*, 3(1), 202. <https://doi.org/10.1007/s44217-024-00309-1>
- Quarder, J., Greefrath, G., Gerber, S., & Siller, H.-S. (2025). Pedagogical content knowledge for simulations and mathematical modelling with digital tools: A quasi-experimental study with pre-service mathematics teachers. *ZDM – Mathematics Education*, 57(2), 395–409. <https://doi.org/10.1007/s11858-025-01673-4>
- Rotem, S. H., & Ayalon, M. (2024). Constructing coherency levels to understand connections among the noticing skills of pre-service mathematics teachers. *Journal of Mathematics Teacher Education*, 27(4), 579–605. <https://doi.org/10.1007/s10857-023-09574-7>
- Sánchez, A., Font, V., & Breda, A. (2022). Significance of creativity and its development in mathematics classes for preservice teachers who are not trained to develop students' creativity. *Mathematics Education Research Journal*, 34(4), 863–885. <https://doi.org/10.1007/s13394-021-00367-w>
- Santagata, R., König, J., Scheiner, T., Nguyen, H., Adleff, A.-K., Yang, X., & Kaiser, G. (2021). Mathematics teacher learning to notice: A systematic review of studies of video-based programs. *ZDM – Mathematics Education*, 53(1), 119–134. <https://doi.org/10.1007/s11858-020-01216-z>

- Scheiner, T., & Amador, J. M. (2025). Noticing-as-design: Generating new possibilities for teacher noticing. *Journal of Mathematics Teacher Education*. <https://doi.org/10.1007/s10857-025-09725-y>
- Scheiner, T., Buchholtz, N., & Kaiser, G. (2024). Mathematical knowledge for teaching and mathematics didactic knowledge: A comparative study. *Journal of Mathematics Teacher Education*, 27(6), 1083–1104. <https://doi.org/10.1007/s10857-023-09598-z>
- Scheiner, T., Godino, J. D., Montes, M. A., Pino-Fan, L. R., & Climent, N. (2022). On metaphors in thinking about preparing mathematics for teaching. *Educational Studies in Mathematics*, 111(2), 253–270. <https://doi.org/10.1007/s10649-022-10154-4>
- Shodiq, L. J., Juniati, D., & Susanah. (2025). Teaching creativity through mathematical lateral thinking problems: A pilot study. *Eurasia Journal of Mathematics, Science and Technology Education*, 21(2), em2574. <https://doi.org/10.29333/ejmste/15913>
- Shure, V., Lehmann, M., Friesen, M., Roesken-Winter, B., & Prediger, S. (2025). Professional development research on promoting productive practices for teachers' handling of typical tasks of mathematics teaching: A systematic review. *ZDM – Mathematics Education*, 57(4), 795–813. <https://doi.org/10.1007/s11858-025-01659-2>
- Stockero, S. L., Van Zoest, L. R., Freeburn, B., Peterson, B. E., & Leatham, K. R. (2022). Teachers' responses to instances of student mathematical thinking with varied potential to support student learning. *Mathematics Education Research Journal*, 34(1), 165–187. <https://doi.org/10.1007/s13394-020-00334-x>
- Sujadi, I., Suprihatiningsih, S., Irfan, M., & Pepkolaj, L. (2025). Pre-service mathematics teachers: Designing context-based tasks. *Infinity Journal*, 14(4), 995–1018. <https://doi.org/10.22460/infinity.v14i4.p995-1018>
- Tinh, P. T., Le, T. T. T., Nguyen, P.-T., Le, C. D., Nguyen, M.-T., & Nguyen, T.-T. (2021). Preparing pre-service teachers for mathematics teaching at primary schools in Vietnam. *Eurasia Journal of Mathematics, Science and Technology Education*, 17(5), em1966. <https://doi.org/10.29333/ejmste/10863>
- van Es, E. A., & Sherin, M. G. (2021). Expanding on prior conceptualizations of teacher noticing. *ZDM – Mathematics Education*, 53(1), 17–27. <https://doi.org/10.1007/s11858-020-01211-4>
- Videla, M. V. M., Perdomo-Díaz, J., Giaconi, V., & Ruz, F. (2026). Profiles of pre-service secondary mathematics teachers' self-perceptions of professional competencies and the opportunities for development. *Mathematics Teacher Education and Development*, 28(1). <https://eric.ed.gov/?id=EJ1513524>
- Weyers, J., König, J., Scheiner, T., Santagata, R., & Kaiser, G. (2024). Teacher noticing in mathematics education: A review of recent developments. *ZDM – Mathematics Education*, 56(2), 249–264. <https://doi.org/10.1007/s11858-023-01527-x>
- Widodo, S. A., Wijayanti, A., Irfan, M., Pusporini, W., Mariah, S., & Rochmiyati, S. (2023). Effects of worksheets on problem-solving skills: Meta-analytic studies. *International Journal of Educational Methodology*, 9(1), 151–167. <https://doi.org/10.12973/ijem.9.1.151>
- Xu, B., Ma, X., Zhang, Y., & Wu, X. (2025). How does mathematical literacy affect creative thinking? Independent effects and differential impacts across proficiency groups. *Acta Psychologica*, 260, 105509. <https://doi.org/10.1016/j.actpsy.2025.105509>
- Zhang, W., Guan, Y., & Hu, Z. (2024). The efficacy of project-based learning in enhancing computational thinking among students: A meta-analysis of 31 experiments and quasi-experiments. *Education and Information Technologies*, 29(11), 14513–14545. <https://doi.org/10.1007/s10639-023-12392-2>
- Zhang, Y., Xin, J. J., Yu, Z., Liu, Y., Zhao, W., Li, N., Li, Y., & Chen, G. (2025). Enhancing preservice teachers' use of dialogic teaching and dynamic visualizations in mathematics classes: Bridging the knowing-doing gap. *International Journal of Science and Mathematics Education*, 23(6), 1793–1823. <https://doi.org/10.1007/s10763-025-10558-7>