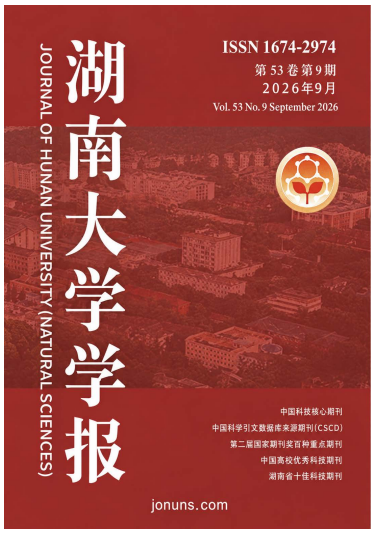


Journal of Hunan University (Natural Sciences)

Vol. 53 No. 9

September 2026

Available online at

https://jonuns.com

Open Access Article

https://doi.org/10.55463/issn.1674-2974.53.9.11

Modeling Pre-Service Teachers' Mitigation Ability Through Pedagogical, Professional, Academic, and Social Competencies: Insights from PLS-SEM Analysis

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Article History:

Received: September 19, 2026
Revised: October 2, 2026
Accepted: October 15, 2026
Published: October 30, 2026

Abstract: Disaster risk mitigation ability is an essential competency for pre-service teachers, enabling them to translate disaster-related knowledge into preparedness and preventive action. This study investigates the relationships between pedagogical, professional, academic, and social competencies and disaster risk mitigation ability among pre-service teachers. A quantitative research design was employed, using survey data collected from 92 undergraduate students enrolled in a teacher education program in Indonesia who had experience with artificial intelligence (AI)-based learning applications. Partial Least Squares Structural Equation Modeling (PLS-SEM) was applied to examine the relationships among the competency domains and mitigation ability. The measurement model demonstrated satisfactory internal consistency reliability; however, the average variance extracted (AVE) values for the four predictor constructs were below the recommended threshold of 0.50, indicating limitations in convergent validity. The structural model explained 25.5% of the variance in mitigation ability ($R^2 = 0.255$). Social competence exhibited the largest positive standardized coefficient ($\beta = 0.361$), followed by pedagogical competence ($\beta = 0.269$) and academic competence ($\beta = 0.047$), whereas professional competence showed a negative coefficient ($\beta = -0.312$). As the statistical significance of these relationships has not yet been consistently verified, the results are interpreted as preliminary associations rather than confirmed hypothesis support. The findings provide an exploratory competency-

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based perspective on disaster risk reduction education and highlight the potential importance of communication, collaboration, and pedagogical competence in preparing future teachers for disaster mitigation activities. Further research with larger samples and refined measurement instruments is recommended.

Keywords: disaster risk mitigation; pre-service teachers; pedagogical competence; professional competence; academic competence; social competence; PLS-SEM.

基于PLS-SEM分析的职前教师灾害减缓能力建模：教学能力、专业能力、学术能力与社会能力的作用

摘要： 灾害风险减缓能力是职前教师的一项重要专业能力，使其能够将灾害相关知识转化为防灾准备和预防行动。本研究探讨职前教师的教学能力、专业能力、学术能力和社会能力与灾害风险减缓能力之间的关系。研究采用定量研究设计，以印度尼西亚某教师教育项目中92名具有人工智能（AI）辅助学习应用使用经验的本科生为调查对象，通过问卷收集数据。采用偏最小二乘结构方程模型（PLS-SEM）分析各能力维度与灾害风险减缓能力之间的关系。测量模型表现出令人满意的内部一致性信度；然而，四个预测变量构念的平均方差提取量（AVE）均低于建议阈值0.50，表明其聚合效度存在一定局限。结构模型能够解释灾害风险减缓能力25.5%的变异（$R^2 = 0.255$）。其中，社会能力表现出最大的正向标准化路径系数（$\beta = 0.361$），其次为教学能力（$\beta = 0.269$）和学术能力（$\beta = 0.047$），而专业能力表现出负向路径系数（$\beta = -0.312$）。由于这些关系的统计显著性尚未得到一致性验证，因此研究结果应被解释为初步统计关联，而非对研究假设的确定性支持。本研究从探索性的能力本位视角为灾害风险降低教育提供了实证依据，并强调沟通、协作以及教学能力在培养未来教师开展灾害减缓活动方面的潜在重要性。未来研究应扩大样本规模，进一步完善测量工具，以提高研究结果的可靠性与适用性。

关键词： 灾害风险减缓；职前教师；教学能力；专业能力；学术能力；社会能力；偏最小二乘结构方程模型（PLS-SEM）。

1. Introduction

The increasing frequency and intensity of disasters, the accelerating impacts of climate change, and growing socio-ecological uncertainty have fundamentally reshaped expectations of the role of education in contemporary society. Education is no longer viewed solely as a mechanism for knowledge transmission but increasingly as a strategic process for developing individuals' capacity to recognize hazards, understand vulnerability, make informed decisions, and undertake preventive actions before disasters occur. Within the framework of disaster risk reduction (DRR), mitigation ability has consequently emerged as a critical educational outcome because it reflects an individual's capacity to identify potential threats, evaluate their consequences, develop preparedness strategies, and actively participate in sustainable risk reduction efforts [1], [2]. Consistent with this shift, recent developments in DRR education demonstrate a transition from information-centred instruction toward more integrated educational approaches that combine disaster literacy, contextual learning, preparedness training, and community engagement to promote meaningful behavioural change [1].

This transformation positions educational institutions as key actors in strengthening disaster resilience. Schools and higher education institutions are expected not only to disseminate scientific knowledge but also to cultivate the values, competencies, and behavioural dispositions required for effective disaster preparedness and risk reduction. Previous studies have demonstrated that safe school initiatives, disaster simulation programmes, project-based learning, and risk communication strategies can successfully narrow the gap between hazard awareness and actual preparedness behaviour [3], [4], [5]. Nevertheless, the effectiveness of these educational interventions depends not merely on curriculum content or instructional materials but fundamentally on the competencies of educators responsible for designing, facilitating, and evaluating the learning process. As a result, the quality of mitigation education is determined not only by what is taught but also by how disaster-related knowledge is transformed into meaningful learning experiences that foster preparedness and resilience [6].

In the educational literature, educator competence is generally conceptualized as a multidimensional construct comprising pedagogical, professional, academic, and social competencies [7]. Although these

competency domains collectively define educators' professional capacity, each represents a distinct dimension that may contribute differently to educational outcomes. Pedagogical competence concerns the ability to design, implement, and evaluate effective learning processes. Professional competence reflects adherence to professional standards, ethical responsibilities, and institutional accountability. Academic competence encompasses scientific reasoning, conceptual understanding, and the systematic application of knowledge, whereas social competence emphasizes communication, collaboration, trust building, and productive interaction with diverse stakeholders. While these competencies are commonly regarded as complementary components of educator professionalism, their respective contributions to disaster mitigation ability cannot be assumed to be equivalent. This distinction is particularly relevant in disaster risk reduction because effective mitigation depends not only on cognitive mastery but also on the capacity to communicate risk, facilitate participation, coordinate collective action, and translate knowledge into practical preparedness [8].

Recent developments in disaster education research have increasingly highlighted the close relationship between educational competencies and disaster risk reduction. First, numerous studies emphasize the importance of integrating DRR into educational curricula while strengthening institutional preparedness through comprehensive school-based approaches [1], [4]. Second, research conducted in high-risk environments consistently demonstrates that non-technical competencies—including communication, coordination, leadership, teamwork, and situational awareness—play a critical role in effective disaster preparedness and emergency response [9], [10]. Third, methodological developments have led to the widespread adoption of Partial Least Squares Structural Equation Modeling (PLS-SEM) as a robust analytical approach for examining predictive relationships among complex latent constructs in educational and social science research [11], [12], [13]. Collectively, these developments suggest that mitigation ability should be understood as a multidimensional educational outcome shaped by the interaction of multiple competency domains rather than by a single dimension of educator competence.

Despite these advances, important gaps remain in the existing literature. Most studies on disaster mitigation education have concentrated primarily on curriculum integration, disaster literacy, school preparedness, or the development of disaster education programmes [1], [4]. While these studies have substantially advanced understanding of the educational role in strengthening resilience, they have provided limited empirical evidence regarding the relative contribution of different educator competency domains to mitigation ability. Conversely, studies focusing on educator competencies have predominantly addressed instrument development, competency validation, or professional development without explicitly linking these competencies to disaster mitigation outcomes. Consequently, the empirical relationship between pedagogical, professional, academic, and social competencies and their comparative contribution to mitigation ability remains insufficiently understood. This limitation highlights the need for an integrated predictive framework capable of simultaneously evaluating the relative influence of multiple educator competencies on mitigation ability, thereby providing a more comprehensive understanding of competency-based disaster risk reduction education.

The identified research gap has important implications for teacher education and competency-based disaster risk reduction programmes. Existing capacity-building initiatives often treat educator competencies as a homogeneous set of professional attributes, assuming that each competency contributes equally to educational effectiveness. Such an assumption may lead to less effective intervention strategies because different competency domains are likely to influence mitigation ability through different mechanisms and with different levels of contribution. Within the present study, AI is used only to define the respondent context: participants were FKIP students with experience using AI-based applications in learning activities. AI is therefore not positioned as an independent construct, mediator, or outcome in the proposed model. Identifying the relative contribution of each competency domain among pre-service teachers is essential for designing more targeted, evidence-based, and effective capacity development strategies that align educational interventions with competencies most relevant to disaster preparedness and mitigation.

Against this background, a clear empirical gap remains regarding the comparative association of pedagogical, professional, academic, and social competencies with mitigation ability among pre-service teachers within a unified analytical framework. Although previous studies have highlighted the importance of educator competence and disaster education independently, limited evidence is available regarding how these competency domains jointly explain mitigation ability when evaluated simultaneously within a single structural model. Addressing this gap represents the primary objective of the present study. By employing a prediction-oriented PLS-SEM approach, this research examines the individual relationships between competency domains and mitigation ability and identifies their relative observed contributions, thereby providing an exploratory empirical foundation for competency-based disaster risk reduction education.

2. Research Aim

This study aims to examine the relative association of pedagogical, professional, academic, and social

competencies with mitigation ability among FKIP pre-service teachers within an integrated educational competency framework. Specifically, the study seeks to (1) evaluate the measurement model of mitigation ability based on the fifteen indicators (MA1-MA15); (2) estimate the structural relationships between the four competency domains and mitigation ability using Partial Least Squares Structural Equation Modeling (PLS-SEM); (3) assess the proportion of variance in mitigation ability explained by the proposed competency model; and (4) provide theoretical, methodological, and practical insights into the development of competency-based disaster risk reduction (DRR) education.

Beyond testing individual relationships, this study identifies the relative observed contribution of each competency domain in explaining mitigation ability. By simultaneously examining pedagogical, professional, academic, and social competencies within a single structural framework, the study advances understanding of how different dimensions of pre-service teacher competence relate to mitigation ability and provides an empirical basis for strengthening disaster risk reduction education through evidence-based competency development. The novelty of this study lies in the development of an integrated competency model that simultaneously examines these four domains in relation to mitigation ability among FKIP students with AI-based learning experience, while treating AI as respondent context rather than as a modeled variable.

3. Literature Review and Hypotheses Development

Pedagogical competence refers to educators' ability to understand learner characteristics, formulate learning objectives, design appropriate instructional strategies, manage classroom interactions, and evaluate learning outcomes. Within the context of disaster risk reduction (DRR), this competency becomes particularly important because key concepts—including hazards, vulnerability, capacity, preparedness, and risk—are often abstract and difficult to translate into meaningful behavioural responses. Consequently, educators must transform these concepts into authentic learning experiences through locally relevant case studies, simulations, project-based activities, reflective discussions, and practical preparedness exercises that enable learners to connect theoretical understanding with real-world mitigation practices.

Recent DRR education literature consistently emphasizes that the effectiveness of mitigation education depends not only on curriculum content but also on pedagogical approaches that successfully connect disaster knowledge with preparedness behaviour [1]. Similarly, the digital competency framework for DRR highlights that educators require strong pedagogical capabilities to transform hazard information, digital resources, and learning technologies into adaptive and risk-responsive educational processes [14]. Collectively, these perspectives suggest that pedagogical competence functions as the instructional mechanism through which disaster knowledge is converted into behavioural readiness and preventive action rather than remaining conceptual understanding alone. Therefore, educators with stronger pedagogical competence are expected to facilitate more effective development of mitigation ability.

Based on this theoretical foundation, Hypothesis 1 (H1) is formulated as follows.

H1. Pedagogical competence has a positive effect on mitigation ability.

Professional competence reflects an educator's ability to perform professional responsibilities in accordance with ethical standards, institutional regulations, accountability, and professional practice. Within disaster education, professional competence contributes to the consistent implementation of school safety programmes, compliance with operational procedures, and the integration of educational responsibilities with learner protection. Evidence from safe-school research indicates that effective implementation of disaster preparedness initiatives depends not only on mitigation content but also on institutional commitment, implementation capacity, and procedural consistency [4]. Likewise, disaster preparedness research highlights that both professional and non-technical competencies are essential because emergency situations require coordinated decision-making, leadership, and shared responsibility across multiple stakeholders [9].

Nevertheless, professional competence may not automatically translate into mitigation ability when it remains focused primarily on administrative responsibilities or procedural compliance without explicitly incorporating disaster preparedness and risk reduction practices. This distinction suggests that the contribution of professional competence depends on the extent to which professional responsibilities are aligned with mitigation objectives. From a theoretical perspective, however, professional competence should strengthen educators' capacity to implement systematic, disciplined, and sustainable mitigation practices. Therefore, a positive relationship is proposed in the conceptual model.

Based on this theoretical foundation, Hypothesis 2 (H2) is formulated as follows.

H2. Professional competence has a positive effect on mitigation ability.

Academic competence refers to the ability to understand scientific concepts, apply analytical reasoning, interpret evidence, and explain phenomena systematically. In disaster education, such competence provides the cognitive foundation required to understand hazard characteristics, causal mechanisms,

exposure, vulnerability, resilience, and risk reduction strategies. Without adequate academic competence, mitigation activities risk becoming procedural routines that lack conceptual understanding and critical reflection.

Research in disaster risk reduction education consistently identifies scientific literacy and disaster knowledge as fundamental prerequisites for understanding why preventive measures are necessary and how they should be implemented [1]. However, knowledge alone does not necessarily produce mitigation behaviour. Effective disaster preparedness requires individuals to transform conceptual understanding into practical action through learning experiences, communication, and participation in social contexts. Accordingly, academic competence is expected to contribute positively to mitigation ability, although its direct contribution may be less substantial than those of pedagogical and social competencies because knowledge acquisition represents only one component of the broader behavioural process underlying disaster preparedness.

Based on this theoretical foundation, Hypothesis 3 (H3) is formulated as follows.

H3. Academic competence has a positive effect on mitigation ability.

Social competence encompasses the ability to communicate effectively, collaborate with others, demonstrate empathy, establish trust, and participate in collective problem-solving. Within the context of disaster risk reduction, these competencies are particularly important because mitigation is inherently a collaborative process rather than an individual activity. Critical mitigation practices—including early warning dissemination, evacuation planning, hazard mapping, community education, and school preparedness—depend on effective coordination, mutual trust, and continuous dialogue among multiple stakeholders. Consequently, the effectiveness of mitigation initiatives is determined not only by what individuals know but also by how successfully they interact, coordinate, and mobilize collective action.

This perspective is supported by the competency review of social work in disaster management, which emphasizes that effective mitigation requires communication, interprofessional collaboration, community engagement, and sustained social support throughout the disaster management process [10]. Likewise, studies examining the integration of indigenous and local knowledge into disaster risk reduction demonstrate that community resilience is strengthened when mitigation activities are developed through participatory approaches that recognize local contexts, cultural values, and social relationships [15]. Collectively, these findings suggest that social competence functions as the enabling mechanism through which disaster knowledge is translated into coordinated preparedness and collective mitigation practices. Accordingly, individuals with stronger social competence are expected to demonstrate greater mitigation ability because they are better equipped to facilitate communication, encourage participation, and coordinate disaster preparedness within educational and community settings.

Based on this theoretical foundation, Hypothesis 4 (H4) is formulated as follows.

H4. Social competence has a positive effect on mitigation ability.

The four hypotheses are developed within an integrated competency framework that conceptualizes mitigation ability as a multidimensional educational outcome. Rather than assuming that educator competencies contribute equally, the proposed model recognizes that each competency domain represents a distinct yet complementary dimension of mitigation education. Academic competence provides the cognitive foundation for understanding disaster risks; pedagogical competence transforms that knowledge into meaningful learning experiences; professional competence ensures that mitigation practices are implemented within ethical, institutional, and professional standards; and social competence facilitates communication, collaboration, and coordinated action among individuals and communities. Viewed together, these competencies form an interconnected system in which the effectiveness of mitigation education depends on the interaction among cognitive, instructional, professional, and social dimensions rather than on any single competency in isolation.

Accordingly, the proposed structural model is designed not only to examine whether each competency exhibits a positive relationship with mitigation ability but also to evaluate the relative contribution of each competency domain in explaining mitigation outcomes. This integrative perspective provides a more comprehensive understanding of educator competencies in disaster risk reduction and establishes the theoretical basis for comparing their predictive roles within a single structural framework.

4. Research Methods

This study employed an explanatory quantitative research design using Partial Least Squares Structural Equation Modeling (PLS-SEM). The selection of PLS-SEM was motivated by the exploratory, prediction-oriented nature of the research objective, which seeks to examine the relative observed contributions of pedagogical, professional, academic, and social competencies to mitigation ability among pre-service teachers. Because the proposed model consists of multiple interrelated latent constructs and emphasizes prediction-oriented theory development rather than strict theory confirmation, PLS-SEM provides an appropriate analytical framework for estimating

complex structural relationships in educational research [12], [16].

The conceptual model comprises four exogenous latent constructs—Pedagogical Competence (PdC), Professional Competence (PrC), Academic Competence (AcC), and Social Competence (ScC)—and one endogenous construct, Mitigation Ability (MtA). Mitigation ability was operationalized using fifteen reflective indicators (MA1–MA15). The structural model was estimated using SmartPLS, which generated indicator loadings, reliability and validity statistics, standardized path coefficients, and the coefficient of determination (R^2) for the endogenous construct. These outputs formed the primary basis for evaluating both the measurement quality and the predictive performance of the proposed model.

The analytical procedure consisted of two complementary stages. The first stage involved evaluation of the measurement model to assess the adequacy of the latent constructs. Indicator reliability was examined through outer loadings, where higher loading values indicate stronger relationships between indicators and their underlying constructs. Consistent with established PLS-SEM guidelines, indicators with loadings above 0.70 were considered satisfactory, whereas indicators within the range of 0.50–0.70 were retained when they demonstrated theoretical relevance and contributed to preserving the conceptual content of the construct [12], [16]. In addition to indicator reliability, the measurement model was evaluated using Cronbach's alpha, rhoA, composite reliability (CR), average variance extracted (AVE), and the heterotrait-monotrait ratio (HTMT) to assess internal consistency, convergent validity, and discriminant validity.

The second stage focused on evaluation of the structural model. Standardized path coefficients were used to examine the direction and relative strength of the relationships between competency domains and mitigation ability, whereas the coefficient of determination (R^2) was used to estimate the proportion of variance in mitigation ability explained by the four educational competencies. To ensure that the estimated relationships were not affected by multicollinearity, collinearity diagnostics were performed using the variance inflation factor (VIF). Together, these analyses provided a comprehensive assessment of both the explanatory capacity and predictive performance of the proposed competency model.

The adoption of PLS-SEM is further justified by the objective of developing a prediction-oriented rather than a confirmatory model. Unlike covariance-based SEM, which primarily evaluates the fit of established theoretical models, PLS-SEM is particularly suitable for studies aiming to identify the relative contribution of multiple predictors and to explore emerging theoretical relationships. Contemporary methodological literature emphasizes the importance of distinguishing explanatory, confirmatory, and predictive modeling so that empirical findings are interpreted in accordance with the analytical purpose of the study [12], [19]. Accordingly, this study interprets indicator loadings, standardized path coefficients, and R^2 values primarily as measures of predictive contribution rather than definitive evidence of causal relationships.

Transparency in model reporting was considered an essential methodological principle throughout the analysis. Because competency-based models may serve as the basis for educational intervention and policy development, the analytical procedures should be sufficiently transparent to facilitate replication and critical evaluation. From an open science perspective, PLS-SEM research should provide clear documentation of analytical decisions, measurement evaluation, and interpretation of structural relationships [20]. Therefore, all reported interpretations are directly linked to the SmartPLS outputs presented in the corresponding tables and figures.

To enhance analytical consistency, the final revision should report one verified set of results from a single SmartPLS bootstrapping output. The present draft retains the available path coefficients and R^2 values while marking bootstrapping statistics that require confirmation before publication. Measurement model evaluation included outer loadings, Cronbach's alpha, rhoA, composite reliability, AVE, and HTMT, whereas structural model evaluation comprised path coefficients, R^2, collinearity statistics (VIF), t-statistics, and p-values. Using one verified output source is necessary to avoid inconsistencies between coefficients, t-statistics, p-values, and hypothesis conclusions.

5. Results

The research data were obtained from 92 undergraduate students from the Faculty of Teacher Training and Education (FKIP) who served as pre-service teacher respondents. This revision uses the terms FKIP students and pre-service teachers consistently throughout the manuscript and avoids generalizing the findings to teachers, lecturers, or educators beyond the sampled population.

The evaluation of the measurement model indicates that the mitigation ability construct is represented by indicators with generally satisfactory outer loadings. Among the fifteen indicators, MA4 exhibited the highest loading (0.835), followed by MA2 (0.794), MA6 (0.782), MA8 (0.780), and MA7 (0.777), suggesting that these indicators provide the strongest representation of the latent construct. The remaining indicators, including MA15, MA10, MA12, MA11, MA9, and MA5, demonstrated loadings ranging from 0.705 to 0.751, indicating acceptable indicator reliability and supporting the internal consistency of the mitigation ability construct.

Two indicators, MA1 (0.621) and MA14 (0.595), were below the commonly recommended threshold of 0.70. Nevertheless, both indicators remained above the minimum acceptable level frequently adopted in prediction-oriented PLS-SEM studies and were retained because they represent conceptually important dimensions of mitigation ability. Consequently, the measurement model prioritizes adequate coverage of the construct domain while maintaining acceptable psychometric performance, rather than maximizing statistical values through the elimination of theoretically meaningful indicators.

Figure 1 illustrates the distribution of outer loadings for the fifteen mitigation ability indicators (MA1–MA15). The reference line at 0.70 demonstrates that the majority of indicators exceeded the commonly accepted criterion for indicator reliability. MA4 emerged as the strongest indicator of the construct, whereas MA14 showed the lowest loading. Despite its comparatively lower loading, MA14 was retained to preserve the conceptual breadth of the mitigation ability construct. This finding suggests that mitigation ability is a multidimensional construct that is not dominated by a single indicator but is collectively represented by multiple dimensions reflecting understanding, preparedness, and the tendency to undertake mitigation actions.

This study involved 92 respondents consisting of undergraduate FKIP students who voluntarily participated in the survey. The sample size was considered acceptable for the exploratory PLS-SEM model because the largest number of structural paths directed at the endogenous construct was four, and the sample exceeded the commonly used minimum-times rule for PLS-SEM. Nevertheless, the sample remains relatively small; therefore, the findings should be interpreted as preliminary and should be validated in future studies with larger and more diverse pre-service teacher samples.

The inclusion criteria required respondents to (1) be active FKIP students, (2) have experience using AI-based applications in learning activities, (3) voluntarily agree to participate in the research, and (4) complete all questionnaire items. Responses with incomplete questionnaires were excluded from the final dataset.

Data were collected using five structured online questionnaires developed through Google Forms, with each questionnaire measuring a different latent construct. The instruments consisted of: Pedagogical Competence, Professional Competence, Academic Competence, Social Competence, Mitigation Ability.

The questionnaire items were designed to measure respondents' perceptions of pedagogical, professional, academic, and social competencies, as well as mitigation ability. AI was used only as a contextual inclusion criterion because respondents had experience using AI-based applications in learning activities; AI was not modeled as an independent variable, mediator, or moderator.

All questionnaire items were measured using a five-point Likert scale, where:

Score Category
1 Strongly Disagree
2 Disagree
3 Neutral
4 Agree
5 Strongly Agree

Higher scores indicate stronger perceptions regarding the measured competency.

The research instruments were developed based on the theoretical framework of educator competencies comprising pedagogical, professional, academic, and social competencies, as well as disaster mitigation competencies identified in the literature on Disaster Risk Reduction (DRR). The questionnaire items were adapted and contextualized for FKIP pre-service teachers and reviewed for content relevance, clarity, and suitability for higher education contexts.

The content validity of the instrument was evaluated through expert judgment by specialists in the relevant fields to ensure the relevance, clarity, and appropriateness of the questionnaire items for measuring the intended constructs.

Data collection was conducted online using Google Forms. The survey invitation was distributed through academic communication channels accompanied by an explanation regarding the purpose of the study. Participation was entirely voluntary, and respondents completed the questionnaires anonymously without providing personally identifiable information.

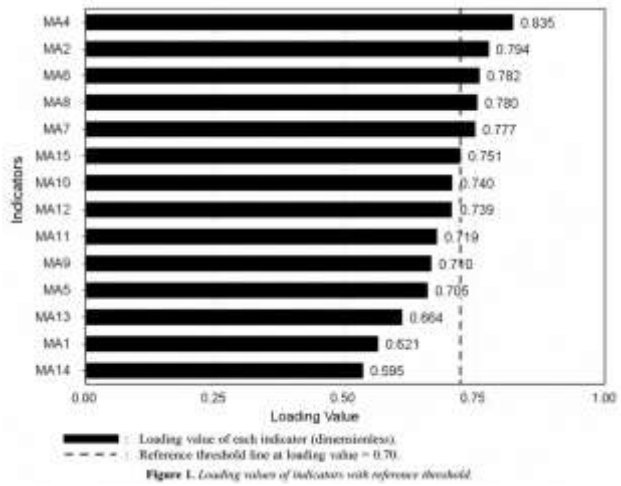
The survey invitation informed participants that the research examined competency domains and mitigation ability among FKIP students with experience using AI-based learning applications.

Participation in this study was entirely voluntary. Before completing the questionnaires, respondents were informed about the objectives of the research, the confidentiality of the collected data, and their right to discontinue participation at any stage without consequences. No personally identifiable information was collected, and all responses were analyzed anonymously for academic research purposes. Ethical approval or exemption information must be inserted in the Declarations section after the authors provide the protocol number and approval date.

The collected data were analyzed using SmartPLS version 4.1.1.8 following the Partial Least Squares Structural Equation Modeling (PLS-SEM) approach. The measurement model was evaluated using outer loadings, Cronbach's alpha, rhoA, Composite Reliability (CR), Average Variance Extracted (AVE), and the Heterotrait–Monotrait Ratio (HTMT).

The structural model was subsequently evaluated using standardized path coefficients, coefficient of determination (R^2), and Variance Inflation Factor (VIF). The statistical significance of the structural relationships was assessed using the bootstrapping procedure with 5,000 subsamples, employing two-tailed testing at a significance level of 5%.

Figure 1. Indicator Loadings for Mitigation Ability



Source: Author's PLS-SEM analysis.

The assessment of internal consistency reliability and convergent validity demonstrates that all constructs achieved satisfactory reliability. As presented in Table 1, Cronbach's alpha and composite reliability (CR) values exceeded the recommended threshold of 0.70 across all latent variables, indicating that the measurement items consistently capture their respective constructs. The consistently high reliability coefficients suggest that the proposed measurement model possesses adequate internal consistency and provides a stable basis for subsequent structural model evaluation.

Although the reliability criteria were fully satisfied, convergent validity was only partially achieved. The Mitigation Ability (MtA) construct reached the recommended AVE threshold (AVE = 0.537), indicating that more than half of the variance of its indicators is explained by the latent construct. In contrast, the AVE values of Pedagogical Competence (0.415), Professional Competence (0.427), Academic Competence (0.464), and Social Competence (0.443) remained below the recommended threshold of 0.50. These findings require cautious interpretation and indicate that the measurement instrument should be refined in future studies.

Nevertheless, the relatively low AVE values should not be interpreted as evidence of an inadequate measurement model. The satisfactory composite reliability, together with the conceptual relevance of the retained indicators, suggests that the constructs remain sufficiently reliable for prediction-oriented analysis. Rather than removing theoretically meaningful indicators solely to improve statistical indices, the present study prioritizes preserving the conceptual coverage of each competency domain. Therefore, the measurement model is considered acceptable for structural analysis, while acknowledging that future studies should further refine the measurement instrument to improve convergent validity.

Table 1. Reliability and Convergent Validity

Construct	Cronbach's Alpha	rho A	Composite Reliability (CR)	AVE	Remarks
Pedagogical Competence (PdC)	0.888	0.88	0.9	0.415	Reliable; AVE below 0.50 and requires cautious interpretation
Professional Competence (PrC)	0.88	0.89	0.89	0.427	Reliable; AVE below 0.50 and requires cautious interpretation
Academic Competence (AcC)	0.93	0.83	0.93	0.464	Reliable; AVE below 0.50 and requires cautious interpretation
Social Competence (ScC)	0.89	0.9	0.9	0.443	Reliable; AVE below 0.50 and requires cautious interpretation
Mitigation Ability (MtA)	0.93	0.94	0.942	0.537	Reliable and valid

Source: SmartPLS and R data processing results.

Discriminant validity was subsequently evaluated using the heterotrait-monotrait ratio (HTMT). As shown in Table 2, all HTMT values were substantially below the conservative threshold of 0.85, ranging from 0.170 to 0.493. These results indicate that each latent construct is empirically distinct from the others, confirming that the indicators measure conceptually different competency domains rather than overlapping dimensions. The satisfactory HTMT results therefore strengthen the overall quality of the measurement model despite the less-than-optimal AVE values observed for several exogenous constructs.

Table 2. Discriminant Validity Based on HTMT

Construct Relationship	HTMT
PdC – PrC	0.21
PdC – AcC	0.21

PdC – ScC	0.21
PdC – MtA	0.22
PrC – AcC	0.29
PrC – ScC	0.33
PrC – MtA	0.18
AcC – ScC	0.49
AcC – MtA	0.17
ScC – MtA	0.31

Source: SmartPLS data processing results.

Collinearity diagnostics further indicate that multicollinearity is not a concern in the proposed structural model. The inner VIF values ranged from 1.003 to 1.384 (AcC = 1.379; PdC = 1.003; PrC = 1.049; ScC = 1.384), which are well below commonly accepted thresholds. These results suggest that each predictor contributes unique explanatory information, allowing the estimated path coefficients to be interpreted without substantial bias caused by multicollinearity.

Structural Model Evaluation

The structural model explains 25.5% of the variance in mitigation ability ($R^2 = 0.255$), indicating a weak-to-moderate level of explanatory power. In the context of educational and behavioural research, this level of explained variance is reasonable because mitigation ability is inherently multidimensional and is likely influenced by numerous factors beyond educator competencies, including disaster experience, institutional preparedness, organizational culture, policy support, and access to disaster-related learning resources. Consequently, the findings suggest that pedagogical, professional, academic, and social competencies constitute meaningful, yet not exhaustive, determinants of mitigation ability.

Table 3. R-square of the Endogenous Construct

Endogenous Variable	R^2	Category
Mitigation Ability (MtA)	0.26	Weak–Medium

Source: R data processing results.

The estimated structural paths reveal distinct patterns of association among the four competency domains. Social competence exhibited the largest observed standardized coefficient (β = 0.361), suggesting that interpersonal communication, collaboration, and social interaction may represent the largest observed contribution to mitigation ability within the proposed model. Pedagogical competence also demonstrated a positive coefficient (β = 0.269), indicating that instructional capability may facilitate mitigation-related knowledge and behaviour. Academic competence showed only a marginal positive relationship (β = 0.047). In contrast, professional competence displayed a negative standardized coefficient (β = -0.312), indicating that its unique contribution, after accounting for the other competency domains, differed from the initially hypothesized direction.

The statistical conclusion for each structural path must be verified using one final SmartPLS bootstrapping output because the available draft values contain inconsistencies between t-statistics and p-values. Until that verification is completed, the coefficient directions and relative magnitudes should be interpreted as preliminary predictive patterns rather than conclusive evidence of causal relationships or formal hypothesis support.

Table 4. Structural Model Path Coefficients

Path	Path Coefficient (β)	t-statistic (verify)	p-value (verify)
PdC → MtA	0.27	2.18 [verify]	0.07 [verify]
PrC → MtA	–0.312	1.81 [verify]	0.23 [verify]
AcC → MtA	0.05	0.27 [verify]	0.87 [verify]
ScC → MtA	0.36	2.4 [verify]	0.08 [verify]

Source: SmartPLS bootstrapping output; t-statistics and p-values require final verification from one output file.

Source: R data processing results.

Source: R bootstrapping results.

6. Discussion

The most notable finding of this study is the largest observed standardized coefficient for social competence compared with the other competency domains. The coefficient (β = 0.361) suggests that communication, collaboration, trust building, and constructive interpersonal interaction may represent an important pathway in the proposed model. This interpretation should remain cautious until the final bootstrapping output is verified, but it is theoretically meaningful because mitigation is fundamentally a collective process rather than solely an individual cognitive activity.

This interpretation is consistent with the review by Sim and He [10], which emphasizes that disaster management competencies extend beyond technical expertise to include relational capabilities such as understanding community needs, engaging vulnerable populations, and mobilizing available resources. Similarly, Motsumi and Nemakonde [15] argue that effective community-based disaster risk reduction (DRR) depends on participatory processes that integrate local knowledge into collective decision-making. Viewed from an educational perspective, the present findings reinforce these arguments by suggesting that individuals with stronger social competence may be better positioned to transform risk-related knowledge into communication, collaboration, and coordinated mitigation actions. In this sense, social competence functions not merely as an interpersonal skill but as a catalyst that enables knowledge to become practical disaster preparedness behaviour.

Nevertheless, these findings should be interpreted with appropriate caution. Although social competence exhibited the largest standardized coefficient, the corresponding structural path did not reach the conventional level of statistical significance ($p < 0.05$). Therefore, the observed relationship should not be interpreted as conclusive evidence of a causal effect but rather as preliminary predictive evidence regarding the relative contribution of different competency domains. This interpretation is consistent with the prediction-oriented nature of PLS-SEM, where the magnitude and direction of relationships can provide valuable theoretical insights even when statistical significance remains limited.

The prominence of social competence is also consistent with recent developments in disaster risk reduction education. Tyas et al. [1] describe a clear shift in DRR education from knowledge transmission toward integrated, collaborative, and participatory learning approaches that actively involve multiple stakeholders. Likewise, D'Ayala et al. [3] emphasize that safer schools should be understood as resilient social systems rather than merely physically protected environments. Students, teachers, families, and educational institutions operate as interconnected actors whose interactions collectively determine preparedness and resilience. Within this broader perspective, social competence serves as the mechanism linking disaster-related knowledge with coordinated educational practice. Without adequate social competence, mitigation knowledge may remain limited to formal instruction. Conversely, strong communication, collaboration, and trust enable disaster-related knowledge to evolve into shared routines, collective preparedness, and a sustainable culture of safety within educational communities.

The second finding indicates a positive association between pedagogical competence and mitigation ability ($\beta = 0.269$). Although this relationship did not achieve statistical significance at the conventional 5% level, its positive direction is consistent with the theoretical expectation proposed in H1 and suggests that pedagogical competence may contribute to the development of mitigation ability. This finding highlights that disaster mitigation cannot be effectively developed through the transmission of factual knowledge alone. Rather, risk-related concepts must be transformed into meaningful learning experiences that enable learners to connect theoretical understanding with practical preparedness. Learning activities such as evacuation simulations, analyses of local disaster cases, vulnerability mapping projects, and reflective discussions following preparedness exercises provide opportunities for learners to internalize mitigation principles through active engagement rather than passive knowledge acquisition.

This interpretation is supported by Senanayake et al. [14], who emphasize that disaster risk reduction (DRR) educators require digital pedagogical competencies to design adaptive and risk-responsive learning environments. Likewise, Nisa and Maharani [21] demonstrate that the successful implementation of the Comprehensive School Safety Framework in Indonesia depends not only on disaster-related knowledge but also on schools' capacity to continuously design, manage, and sustain educational programmes. Viewed from this perspective, pedagogical competence functions as the mechanism through which disaster knowledge is transformed into structured learning experiences that cultivate preparedness and encourage appropriate mitigation behaviour.

The present findings also contribute to the broader literature on educational competencies by suggesting that pedagogical competence plays a more specific role than is commonly acknowledged. While pedagogy is frequently discussed as a general teaching competency, the current results indicate that, within the context of disaster education, it serves as the bridge connecting academic knowledge with behavioural preparedness. Educators with stronger pedagogical competence are better positioned to contextualize disaster concepts, sequence learning from conceptual understanding to practical application, and evaluate whether learners are capable of applying mitigation principles in realistic situations. Consequently, although social competence emerged as the strongest predictor, pedagogical competence appears to provide an essential instructional foundation that enables mitigation knowledge to be translated into preparedness-oriented learning.

The third finding concerns the relatively small positive coefficient observed for academic competence ($\beta = 0.047$). Although the direction of the relationship is consistent with H3, the magnitude of the coefficient suggests that academic competence alone contributed only marginally to the explanation of mitigation ability in this sample. This finding provides an important perspective because educational practice often assumes that increasing conceptual knowledge will automatically improve disaster preparedness.

This interpretation is consistent with previous DRR research emphasizing that disaster literacy becomes meaningful only when integrated with participation, practical experience, and local contextual engagement [1], [15]. From a PLS-SEM perspective, the limited direct contribution of academic competence may indicate that its influence is realized primarily through indirect pathways, particularly via pedagogical competence that transforms knowledge into learning experiences and social competence that facilitates collaborative mitigation practices. Accordingly, academic competence should be regarded as a necessary but insufficient condition for developing mitigation ability, highlighting the importance of integrating cognitive, pedagogical, and social dimensions within disaster risk reduction education.

The relatively small coefficient of academic competence also carries important practical implications. The findings suggest that mitigation training programmes focusing primarily on conceptual knowledge may improve learners' understanding of disaster-related issues but may not necessarily translate into effective mitigation behaviour. Knowledge concerning hazard types, causes, consequences, and disaster mechanisms should therefore be complemented by communication exercises, collaborative discussions, evacuation simulations, and problem-based learning activities that encourage learners to apply disaster knowledge in realistic contexts.

The fourth finding concerns the negative standardized coefficient observed for professional competence ($\beta = -0.312$). From a theoretical perspective, H2 proposed a positive relationship between professional competence and mitigation ability; however, the empirical model revealed the opposite direction. Although this relationship did not achieve statistical significance, the negative coefficient represents an interesting pattern that warrants careful interpretation rather than immediate rejection. Professional competence, as conceptualized in this study, reflects mastery of professional responsibilities, ethical standards, task performance, and institutional obligations. These dimensions, however, may not necessarily correspond directly to competencies required for disaster mitigation.

Within educational settings, professional competence is often associated with administrative responsibilities, compliance with institutional regulations, and adherence to established professional standards. While these attributes are essential for educational quality, they do not automatically foster adaptive decision-making, collaborative problem-solving, or preparedness behaviours unless disaster risk reduction (DRR) responsibilities are explicitly embedded within professional practice. Therefore, the observed negative coefficient may reflect a distinction between procedural professionalism and the adaptive competencies required for effective mitigation, rather than indicating that professionalism itself hinders mitigation ability.

From a methodological perspective, the interpretation of a negative path coefficient should be considered within the broader context of the structural model rather than in isolation. Hair and Alamer [12] and Sarstedt et al. [22] emphasize that the interpretation of structural coefficients in PLS-SEM should account for prediction objectives, measurement quality, and the interrelationships among latent constructs. In the present model, professional competence may share variance with pedagogical and social competencies, while its unique contribution after controlling for these related constructs is represented by the negative standardized coefficient. Accordingly, this finding should be interpreted as a relative contribution within the multivariate model rather than as evidence that professional competence harms mitigation ability.

Substantively, these findings may indicate that professional competence contributes to disaster mitigation only when it is accompanied by pedagogical capability and social engagement. A professional orientation that emphasizes compliance with procedures without simultaneously strengthening communication, collaboration, and adaptive decision-making may have limited relevance for disaster preparedness. This interpretation is consistent with research on non-technical competencies in all-hazard environments, which demonstrates that effective disaster preparedness depends not only on professional expertise but also on communication, situational awareness, teamwork, and coordinated decision-making [4]. Consequently, the unexpected direction of H2 provides an opportunity to reconsider how professional competence is conceptualized within disaster education. Rather than viewing professionalism solely in terms of technical expertise and institutional responsibility, future competency frameworks may benefit from explicitly integrating disaster preparedness, safety leadership, and DRR responsibilities as essential components of professional educational practice.

From a methodological perspective, the present findings further demonstrate the value of adopting a prediction-oriented PLS-SEM approach for investigating complex educational competency models. Chin et al. [17] argue that causal-predictive modeling enables researchers to examine the relative contribution of multiple latent constructs rather than merely confirming established theoretical relationships. Likewise, Demir and Uşak [23] emphasize that the application of PLS-SEM in educational research should be accompanied by rigorous and transparent reporting to avoid oversimplified interpretations of relationships among latent variables. Zeng et al. [18] similarly stress that both the implementation and reporting of PLS-SEM require methodological rigor to ensure reliable and meaningful interpretation. Within this context, the present study illustrates the analytical value of PLS-SEM by revealing that four competency domains, although theoretically regarded as equally important, exhibit substantially different empirical contributions to mitigation ability. Specifically, social and pedagogical competencies emerged as the dominant predictive pathways, academic competence contributed only marginally as a direct cognitive foundation, whereas professional competence displayed an unexpected negative coefficient that invites further theoretical refinement rather than immediate rejection.

Collectively, these findings reinforce the argument that mitigation ability should be conceptualized as an integrative educational competency rather than as the outcome of a single knowledge domain. Disaster mitigation cannot be adequately explained by factual disaster knowledge, procedural compliance, or general

professional expertise in isolation. Instead, mitigation ability develops through the interaction of complementary competencies in which academic knowledge is transformed into meaningful learning experiences through pedagogical competence, professional competence is aligned with safety-oriented educational responsibilities, and social competence enables communication, collaboration, and collective decision-making. This integrative perspective extends the disaster risk reduction (DRR) literature by suggesting that the combined social-pedagogical dimension constitutes the most promising pathway for strengthening mitigation capacity within educational settings. From a policy perspective, these findings also imply that school-based DRR programmes should position educators not only as knowledge transmitters but also as facilitators of collaborative learning, community engagement, and preparedness-oriented educational practices.

The structural model also provides a meaningful interpretation of the observed coefficient of determination ($R^2 = 0.255$). Although the model explains 25.5% of the variance in mitigation ability, this level of explanatory power is reasonable within the context of educational and behavioural research, where human behaviour is influenced by numerous interrelated factors beyond individual competencies. Disaster experience, institutional preparedness, leadership support, school safety culture, access to disaster-related information, and inter-organizational collaboration may all contribute substantially to mitigation ability but were intentionally excluded from the present model to maintain its focus on educator competencies. Consequently, the explained variance should not be interpreted as a limitation of the model but rather as evidence that competency-based interventions represent one important component within a broader disaster resilience system. These findings therefore highlight the need to complement competency development with institutional governance, continuous preparedness training, community participation, and context-based disaster education to achieve more comprehensive mitigation outcomes.

The convergent validity results should likewise be interpreted within the broader context of instrument development. Although the AVE values of several exogenous constructs remained below the recommended threshold of 0.50, the satisfactory composite reliability and consistently low HTMT values (<0.85) indicate that the measurement model retains acceptable psychometric quality for prediction-oriented analysis. Rather than focusing exclusively on maximizing statistical indices, the present study prioritizes preserving the conceptual integrity of the competency constructs while acknowledging that future refinement of the measurement instrument may further improve convergent validity.

From a measurement perspective, the findings also underscore the importance of transparent evaluation of the measurement model in PLS-SEM research. The loading distribution of indicators MA1–MA15 demonstrates that mitigation ability is represented by indicators with varying levels of contribution, reflecting the multidimensional nature of the construct. Hair and Alamer [12] emphasize that measurement decisions in PLS-SEM should integrate statistical criteria with considerations of content validity rather than relying exclusively on numerical thresholds. This principle is particularly relevant for mitigation research because mitigation ability encompasses multiple interrelated dimensions, including disaster knowledge, preparedness, communication, and behavioural action. Consequently, retaining indicators with relatively lower loadings may be methodologically justified when those indicators capture theoretically important aspects of the construct that are not adequately represented by stronger indicators. Such an approach contributes to a more comprehensive representation of mitigation ability while preserving the substantive validity of the measurement model.

The findings also have important implications for curriculum design in disaster risk reduction education. Rather than presenting mitigation as an isolated instructional topic, the results suggest that mitigation education should be structured as a progressive competency-development process. Such a process begins with establishing a sound academic understanding of disaster risks, followed by transforming conceptual knowledge into meaningful learning experiences through pedagogical practice, strengthening communication and collaborative problem-solving through social interaction, and ultimately embedding these competencies within professional educational responsibilities. This sequential integration enables the four competency domains to complement and reinforce one another, thereby supporting the development of comprehensive mitigation ability rather than fragmented knowledge acquisition.

From an instructional perspective, educators may operationalize this integrated approach by using locally relevant disaster scenarios as authentic learning contexts. Learners can be engaged in hazard identification, community-based risk mapping, discussions on the respective roles of families, schools, and local communities, and reflective evaluation through disaster simulations and preparedness exercises. Such learning experiences encourage students to move beyond conceptual understanding toward the practical application of mitigation knowledge. Consequently, disaster mitigation becomes an integral component of the educational process that systematically cultivates preparedness, adaptive decision-making, and responsible action rather than functioning as an additional curriculum topic.

The present study also offers several contributions to the development of disaster education research. Theoretically, it advances the understanding of mitigation ability by proposing an integrated competency framework that simultaneously incorporates pedagogical, professional, academic, and social competencies within a single predictive model. The findings demonstrate that these competency domains do not contribute equally but instead exhibit distinct empirical roles, thereby providing a more differentiated perspective on how educator competencies relate to mitigation outcomes.

Methodologically, this study illustrates the usefulness of PLS-SEM for examining prediction-oriented educational models involving multiple interrelated latent constructs. By systematically evaluating indicator loadings (MA1–MA15), measurement reliability, convergent and discriminant validity, structural path coefficients, and the explanatory power of the model, the analysis provides a comprehensive basis for interpreting the relative contribution of each competency domain to mitigation ability. This approach offers a transparent analytical framework that can support future studies investigating complex educational competency models.

From a practical perspective, the findings indicate that strengthening mitigation ability requires educational interventions that extend beyond increasing disaster-related knowledge alone. Greater emphasis should be placed on developing risk communication, collaborative learning, contextual and problem-based instructional design, and the integration of disaster preparedness and safety responsibilities into professional educational practice. Such an approach has the potential to strengthen not only individual preparedness but also the collective capacity of educational institutions to foster a sustainable culture of disaster resilience.

7. Conclusions and Suggestions for Practical Use

This study indicates that mitigation ability among FKIP pre-service teachers may be more closely associated with social and pedagogical competencies than with academic or professional competence considered in isolation. The proposed structural model explains 25.5% of the variance in mitigation ability, indicating that competency domains constitute meaningful but incomplete predictors of mitigation outcomes. Among the four competency domains, social competence exhibited the largest observed standardized coefficient ($\beta = 0.361$), followed by pedagogical competence ($\beta = 0.269$), academic competence ($\beta = 0.047$), and professional competence ($\beta = -0.312$). These findings suggest that mitigation ability is supported by competencies that facilitate communication, collaborative learning, and the transformation of knowledge into action, although the final significance conclusions must be verified from a single SmartPLS bootstrapping output.

These conclusions, however, should be interpreted with appropriate caution because none of the structural relationships reached statistical significance at the conventional 5% level in the bootstrapping analysis. Accordingly, the findings should be regarded as preliminary predictive evidence rather than definitive confirmation of causal relationships or formal hypothesis support. The principal contribution of this study therefore lies in proposing an initial predictive framework that clarifies the relative empirical roles of pedagogical, professional, academic, and social competencies in explaining mitigation ability, while simultaneously identifying priorities for further refinement of both the measurement instrument and the theoretical model.

From a practical perspective, the findings suggest that educational institutions should adopt a more integrated approach to disaster risk reduction education by emphasizing risk communication, collaborative learning, simulation-based instruction, problem-based learning, and stronger partnerships between schools and local communities. Educator development programmes should therefore extend beyond the delivery of disaster-related content to include pedagogical strategies that facilitate experiential learning as well as social competencies that strengthen coordination, participation, and collective preparedness. Furthermore, professional competence should be reconceptualized to explicitly incorporate disaster safety, preparedness, and disaster risk reduction (DRR) responsibilities as integral components of professional educational practice rather than treating them as complementary activities.

Future research should seek to expand the proposed model by incorporating additional determinants of mitigation ability, including disaster experience, school safety culture, institutional support, and participation in disaster risk reduction training. Examining mediating and indirect relationships among academic, pedagogical, professional, and social competencies may also provide a more comprehensive understanding of the mechanisms through which educator competencies contribute to mitigation ability. Such developments would strengthen both the predictive capability and the theoretical robustness of competency-based models for disaster risk reduction education.

Acknowledgments

The authors gratefully acknowledge the Institute for Research and Community Service (LPPM), Universitas Siliwangi, for its support in conducting this research. We also thank all participants and everyone who contributed their time, assistance, and insights to the successful completion of this study.

Author Contributions

Conceptualization: Wahidin and Diana Hernawati. Methodology: Wahidin. Software: Diana Hernawati Hernawati. Validation: Wahidin, Diana Hernawati, and Soegianto Soelistiono. Formal Analysis: Diana. Investigation: Wahidin. Resources: Diana Hernawati and Soegianto Soelistiono. Data Curation: Wahidin. Writing—Original Draft Preparation: Wahidin and Diana Hernawati: Writing—Review and Editing: Diana Hernawati and Soegianto Soelistiono. Visualization: Diana Hernawati. Supervision: Wahidin and Soegianto Soelistiono. Project Administration: Diana Hernawati. All authors have read and agreed to the published version of the manuscript.

Funding

Funding Acquisition: Not applicable.

Institutional Review Board Statement

Participants were informed about the purpose of the study and the voluntary nature of their participation. Informed consent was obtained before data collection, and participant identities were kept confidential.

Informed Consent Statement

Informed consent was obtained from all respondents before they completed the anonymous online questionnaire.

Data Availability Statement

The data presented in this study are available from the corresponding author upon reasonable request. The datasets are not publicly available because they contain anonymous responses from research participants and are subject to ethical and privacy considerations.

Conflicts of Interest

The authors declare that there are no financial, institutional, commercial, or personal conflicts of interest that could have influenced the design, execution, interpretation, or publication of this research.

References

[1] R. A. Tyas, I. Wilujeng, D. Rosana, H. Kuswanto, and D. Purwasih, “A review of disaster risk reduction education implementation: Integration, trends, and trajectories,” Soc. Sci. Humanit. Open, vol. 12, p. 102015, 2025, doi: https://doi.org/10.1016/j.ssaho.2025.102015.

[2] S. M. Geddam and C. A. Raj Kiran, “Enhancing disaster management effectiveness: An integrated analysis of key factors and practical strategies through Structural Equation Modeling (SEM) and Scopus Data Text Mining,” Geohazard Mech., vol. 2, no. 2, pp. 95–107, 2024, doi: 10.1016/j.ghm.2024.03.001.

[3] D. D’Ayala, C. Galasso, and A. Nassirpour, “Resilient communities through safer schools,” Int. J. Disaster Risk Reduct., vol. 45, p. 101446, 2020, doi: 10.1016/j.ijdrr.2019.101446.

[4] B. Kingston, S. A. Mattson, and A. Dymnicki, “Building Schools’ Readiness to Implement a Comprehensive Approach to School Safety,” Clin. Child Fam. Psychol. Rev., vol. 21, no. 4, pp. 433–449, 2018, doi: 10.1007/s10567-018-0264-7.

[5] S. Hawsawi, A. Al Thobaity, and M. Saleh, “The impact of simulated education and training on undergraduate students’ disaster evacuation competencies,” Adv. Med. Educ. Pract., vol. 16, pp. 189–203, 2025, doi: 10.2147/AMEP.S480812.

[6] Q. Fu and X. Zhang, “Promoting community resilience through disaster education: Review of community-based interventions with a focus on teacher resilience and well-being,” PLoS One, vol. 19, no. 1, p. e0296393, 2024, doi: 10.1371/journal.pone.0296393.

[7] A. E. Legate, J. F. Hair, J. L. Chretien, and J. J. Risher, “PLS-SEM: Prediction-oriented solutions for HRD researchers,” Hum. Resour. Dev. Q., vol. 34, no. 1, pp. 91–109, 2023, doi: 10.1002/hrdq.21466.

[8] M. Abunyewah et al., “Influence of personal and collective social capital on flood preparedness and community resilience: Evidence from Old Fadama, Ghana,” Int. J. Disaster Risk Reduct., vol. 94, p. 103790, 2023, doi: 10.1016/j.ijdrr.2023.103790.

[9] H. Hu, M. He, H. Chen, S. Liu, and W. Li, “Nontechnical Competency Framework for Health Professionals in All-Hazard Emergency Environment: A Systematic Review,” Disaster Med. Public Health Prep., vol. 15, no. 2, pp. 255–265, 2021, doi: 10.1017/dmp.2019.146.

[10]T. Sim and M. He, “Social work competence in disaster management: an integrative review,” Eur. J. Soc. Work, vol. 27, no. 1, pp. 83–95, 2024, doi: 10.1080/13691457.2022.2092455.

[11]H. M. Lin, M. H. Lee, J. C. Liang, H. Y. Chang, and P. Huang, “A review of using partial least square structural equation modeling in e-learning research,” Br. J. Educ. Technol., vol. 51, no. 4, pp. 1354–1372, 2020, doi: 10.1111/bjet.12890.

[12]J. Hair and A. Alamer, “Partial Least Squares Structural Equation Modeling (PLS-SEM) in second language and education research: Guidelines using an applied example,” Res. Methods Appl. Linguist., vol. 1, no. 3, p. 100027, 2022, doi: https://doi.org/10.1016/j.rmal.2022.100027.

[13]A. E. Legate, C. M. Ringle, and J. F. Hair, “PLS-SEM: A method demonstration in the R statistical environment,” Hum. Resour. Dev. Q., vol. 35, no. 4, pp. 501–529, 2024, doi: 10.1002/hrdq.21517.

[14]A. C. Senanayake, A. Samarakkody, and C. Malalgoda, “Digital Competencies, Disaster Risk Reduction, and Education: An Introduction to the Digital Competency Framework to Develop Digital Pedagogical Competencies of Educators in Disaster Risk Reduction BT - Climate Change Adaptation in the Built Environment,” Cham: Springer, 2025, pp. 469–497. doi: 10.1007/978-3-031-75826-3_20.

[15]M. M. Motsumi and L. D. Nemakonde, “A framework to integrate indigenous knowledge into disaster risk reduction to build disaster resilience: insights from rural South Africa,” Disaster Prev. Manag. An Int. J., vol. 33, no. 6, pp. 73–85, 2024, doi: 10.1108/dpm-08-2024-0220.
[16]M. Sarstedt, C. M. Ringle, and J. F. Hair, “Partial Least Squares Structural Equation Modeling BT - Handbook of Market Research,” Cham: Springer, 2022, pp. 587–632. doi: 10.1007/978-3-319-57413-4_15.
[17]W. Chin, J. H. Cheah, and Y. Liu, “Demystifying the role of causal-predictive modeling using partial least squares structural equation modeling in information systems research,” Ind. Manag. Data Syst., vol. 120, no. 12, pp. 2161–2209, 2020, doi: 10.1108/imds-10-2019-0529.
[18]N. Zeng, Y. Liu, and P. Gong, “Do right PLS and do PLS right: A critical review of the application of PLS-SEM in construction management research,” Front. Eng. Manag., vol. 8, pp. 356–369, 2021, doi: 10.1007/s42524-021-0153-5.
[19]G. Shmueli, M. Sarstedt, and J. F. Hair, “Predictive model assessment in PLS-SEM: guidelines for using PLSpredict,” Eur. J. Mark., vol. 53, no. 11, pp. 2322–2347, 2019, doi: 10.1108/ejm-02-2019-0189.
[20]S. J. Adler, P. N. Sharma, and L. Radomir, “Toward open science in PLS-SEM: Assessing the state of the art and future perspectives,” J. Bus. Res., vol. 169, p. 114291, 2023, doi: 10.1016/j.jbusres.2023.114291.
[21]J. Nisa and Y. N. Maharani, “Success, Challenges and Future Prospects of the Implementation of Comprehensive School Safety Framework (CSSF) in Indonesia (Case Study at CSSF Aceh and Sleman),” IOP Conf. Ser. Earth Environ. Sci., vol. 1479, no. 1, p. 12035, 2025, doi: 10.1088/1755-1315/1479/1/012035.
[22]J. F. Hair, C. M. Ringle, M. Sarstedt, and G. T. M. Hult, “A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM),” 2022.
[23]S. Demir and M. Usak, “Analyzing the Implementation of PLS-SEM in Educational Technology Research: A Review of the Past 10 Years,” SAGE Open, vol. 15, no. 2, 2025, doi: 10.1177/21582440251345950.

参考文献

[1] TYAS R. A., WILUJENG I., ROSANA D., KUSWANTO H., PURWASIH D. 减少灾害风险教育实施情况综述：整合、趋势与发展路径[J]. Social Sciences & Humanities Open, 2025, 12: 102015. DOI: 10.1016/j.ssaho.2025.102015.
[2] GEDDAM S. M., RAJ KIRAN C. A. 提升灾害管理效能：基于结构方程模型（SEM）与Scopus数据文本挖掘的关键因素及实践策略综合分析[J]. Geohazard Mechanics, 2024, 2(2): 95–107. DOI: 10.1016/j.ghm.2024.03.001.
[3] D’AYALA D., GALASSO C., NASSIRPOUR A. 通过建设更安全的学校增强社区韧性[J]. International Journal of Disaster Risk Reduction, 2020, 45: 101446. DOI: 10.1016/j.ijdrr.2019.101446.
[4] KINGSTON B., MATTSON S. A., DYMNICKI A. 提升学校实施综合性校园安全措施的准备能力[J]. Clinical Child and Family Psychology Review, 2018, 21(4): 433–449. DOI: 10.1007/s10567-018-0264-7.
[5] HAWSAWI S., AL THOBAITY A., SALEH M. 模拟教育与培训对本科生灾害疏散能力的影响[J]. Advances in Medical Education and Practice, 2025, 16: 189–203. DOI: 10.2147/AMEP.S480812.
[6] FU Q., ZHANG X. 通过灾害教育促进社区韧性：聚焦教师韧性与福祉的社区干预措施综述[J]. PLoS ONE, 2024, 19(1): e0296393. DOI: 10.1371/journal.pone.0296393.
[7] LEGATE A. E., HAIR J. F., CHRETIEN J. L., RISHER J. J. 偏最小二乘结构方程模型（PLS-SEM）：面向人力资源开发研究者的预测导向解决方案[J]. Human Resource Development Quarterly, 2023, 34(1): 91–109. DOI: 10.1002/hrdq.21466.
[8] ABUNYEWAH M., et al. 个人与集体社会资本对洪水防灾准备和社区韧性的影响：来自加纳旧法达马地区的证据[J]. International Journal of Disaster Risk Reduction, 2023, 94: 103790. DOI: 10.1016/j.ijdrr.2023.103790.
[9] HU H., HE M., CHEN H., LIU S., LI W. 全灾种应急环境下卫生专业人员非技术能力框架：系统性综述[J]. Disaster Medicine and Public Health Preparedness, 2021, 15(2): 255–265. DOI: 10.1017/dmp.2019.146.
[10] SIM T., HE M. 灾害管理中的社会工作能力：整合性综述[J]. European Journal of Social Work, 2024, 27(1): 83–95. DOI: 10.1080/13691457.2022.2092455.
[11] LIN H. M., LEE M. H., LIANG J. C., CHANG H. Y., HUANG P. 偏最小二乘结构方程模型在电子学习研究中应用的综述[J]. British Journal of Educational Technology, 2020, 51(4): 1354–1372. DOI: 10.1111/bjet.12890.
[12] HAIR J., ALAMER A. 偏最小二乘结构方程模型（PLS-SEM）在第二语言与教育研究中的应用：基于实例的操作指南[J]. Research Methods in Applied Linguistics, 2022, 1(3): 100027. DOI: 10.1016/j.rmal.2022.100027.
[13] LEGATE A. E., RINGLE C. M., HAIR J. F. 偏最小二乘结构方程模型（PLS-SEM）：在R统计环境中的方法演示[J]. Human Resource Development Quarterly, 2024, 35(4): 501–529. DOI: 10.1002/hrdq.21517.
[14] SENANAYAKE A. C., SAMARAKKODY A., MALALGODA C. 数字能力、减少灾害风险与教育：面向灾害风险减缓教育者数字教学能力培养的数字能力框架导论[M]//Climate Change Adaptation in the Built Environment. Cham: Springer, 2025: 469–497. DOI: 10.1007/978-3-031-75826-3_20.
[15] MOTSUMI M. M., NEMAKONDE L. D. 将本土知识融入减少灾害风险以增强灾害韧性的框架：来

自南非农村地区的启示[J]. Disaster Prevention and Management: An International Journal, 2024, 33(6): 73–85. DOI: 10.1108/dpm-08-2024-0220.
[16] SARSTEDT M., RINGLE C. M., HAIR J. F. 偏最小二乘结构方程模型[M]//Handbook of Market Research. Cham: Springer, 2022: 587–632. DOI: 10.1007/978-3-319-57413-4_15.
[17] CHIN W., CHEAH J. H., LIU Y. 解析偏最小二乘结构方程模型在信息系统研究中因果预测建模的作用[J]. Industrial Management & Data Systems, 2020, 120(12): 2161–2209. DOI: 10.1108/imds-10-2019-0529.
[18] ZENG N., LIU Y., GONG P. 正确应用PLS并规范实施PLS分析：对偏最小二乘结构方程模型在建设管理研究中应用的批判性综述[J]. Frontiers of Engineering Management, 2021, 8: 356–369. DOI: 10.1007/s42524-021-0153-5.
[19] SHMUELI G., SARSTEDT M., HAIR J. F. 偏最小二乘结构方程模型的预测模型评估：PLSpredict使用指南[J]. European Journal of Marketing, 2019, 53(11): 2322–2347. DOI: 10.1108/ejm-02-2019-0189.
[20] ADLER S. J., SHARMA P. N., RADOMIR L. 迈向偏最小二乘结构方程模型研究中的开放科学：研究现状评估与未来展望[J]. Journal of Business Research, 2023, 169: 114291. DOI: 10.1016/j.jbusres.2023.114291.
[21] NISA J., MAHARANI Y. N. 印度尼西亚综合学校安全框架（CSSF）实施的成效、挑战与未来前景：亚齐和斯莱曼的案例研究[J]. IOP Conference Series: Earth and Environmental Science, 2025, 1479(1): 012035. DOI: 10.1088/1755-1315/1479/1/012035.
[22] HAIR J. F., RINGLE C. M., SARSTEDT M., HULT G. T. M. 偏最小二乘结构方程模型（PLS-SEM）入门指南[M]. 2022.
[23] DEMIR S., USAK M. 教育技术研究中偏最小二乘结构方程模型应用情况分析：过去十年的研究综述[J]. SAGE Open, 2025, 15(2). DOI: 10.1177/21582440251345950.

Manuscript Information
Word count: 10,685 words (excluding references).
Peer-Review Record

Fast-track status: Not fast-tracked.
First-round reviews received: 3 reports.
Revision cycles completed: 3 rounds.
Final version submitted: October 15, 2026

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