

Literature Review: Exploring the Relationship Between Students' Mathematical Generalization Ability and Mathematical Resilience

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ABSTRACT

This study is a literature review that aims to examine the relationship between mathematical generalization ability and mathematical resilience in the context of mathematics learning. The review explores how these two constructs interact to support students' learning success. The research employed a qualitative content analysis approach to analyze relevant national and international journal articles published between 2015 and 2025 that discuss mathematical generalization and resilience. The results indicate that mathematical generalization is a high-level cognitive skill that enables students to identify patterns, formulate general rules, and connect mathematical concepts abstractly. Meanwhile, mathematical resilience is an affective factor that fosters persistence, self-confidence, and a positive attitude toward learning challenges. The review also reveals that these two constructs are reciprocally related: resilience supports the continuity of the cognitive process in forming generalizations, while successful generalization strengthens students' confidence and perseverance in learning mathematics. Therefore, effective mathematics instruction should be designed integratively by balancing cognitive exercises (developing generalization) and affective reinforcement (building resilience). This study provides a theoretical foundation for developing instructional strategies that enhance students' higher-order thinking skills and emotional endurance in facing mathematical challenges.

Keywords: *Diff mathematical generalization, mathematical resilience, cognitive ability, affective factors, literature study.*

1) INTRODUCTION

Mathematics education serves as an essential foundation for developing students' critical and analytical thinking skills. In Indonesia, international assessments such as the Programme for International Student Assessment (PISA) 2022 show that Indonesian students' mathematical performance remains relatively low compared to the OECD average (OECD, 2022). This condition indicates that mathematics learning in Indonesia continues to face serious challenges, both in cognitive and affective aspects. Therefore, strengthening higher-order thinking skills and fostering resilient learning characteristics are crucial priorities for improving the quality of mathematics education.

One important cognitive aspect that needs to be developed is mathematical generalization ability. Mathematical generalization refers to students' ability to recognize patterns, discover relationships

Paper presented at The 2nd ICONETT, 2025
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among elements, and express general forms based on observed structures (Dwirahayu et al., 2018). This ability forms the foundation for students to develop reasoning skills and algebraic thinking. According to Novantoro et al., (2025) the generalization process helps students build new concepts from previous learning experiences through identifying similarities and differences. Thus, enhancing students' mathematical generalization ability not only strengthens logical reasoning but also reinforces conceptual connections within mathematics.

In addition to cognitive aspects, affective aspects such as mathematical resilience play an equally important role in students' success in learning mathematics. Mathematical resilience refers to students' ability to persevere and remain persistent when facing difficulties in understanding mathematical concepts (Johnston-Wilder & Lee, 2024). Students with high resilience tend to exhibit strong self-confidence, perseverance in learning, and a willingness to engage in discussions and reflect on errors. A study conducted by Pulungan et al., (2024) shows that resilience contributes to shaping positive attitudes toward mathematics and can reduce math anxiety, which often hinders students' learning processes.

Furthermore, various studies indicate that mathematical generalization ability is not only linked to abstract thinking skills but is also influenced by learning experiences that provide opportunities for students to explore patterns independently. Instruction that places excessive emphasis on procedures often prevents students from recognizing interconceptual relationships, leading to suboptimal development of generalization. This is consistent with the findings of Warren & Cooper (2006), who assert that exploratory activities and visual representations help students construct general rules more flexibly. Therefore, learning approaches should provide ample opportunities for exploration, representation, and deep reasoning.

Interestingly, mathematical generalization and mathematical resilience are two complementary constructs. Generalization enables students to build broader conceptual understanding, while resilience supports emotional endurance and motivation to solve complex problems. The integration of these two constructs allows students not only to comprehend mathematical concepts deeply but also to possess strong perseverance when engaging in problem-solving processes (Johnston-Wilder & Lee, 2024). However, research that explicitly examines the relationship between mathematical generalization ability and mathematical resilience remains relatively limited, both nationally and internationally.

Thus, the development of mathematical generalization ability and mathematical resilience cannot be separated from holistic instructional design. Learning that integrates abstract reasoning, pattern-based exploration, and emotional as well as social support has been shown to significantly influence students' competency development. Hoogmoed et al., (2024) demonstrate that the interaction between cognitive and affective aspects is a crucial determinant of success in learning mathematics.

Therefore, this literature review aims to examine in depth the relationship between mathematical generalization ability and mathematical resilience within the context of mathematics education. This review outlines the definitions of each construct, their characteristics, and empirical findings that indicate potential connections between the two. Through this examination, it is expected that a strong theoretical foundation can be established to develop instructional strategies that not only enhance students' abstract thinking skills but also foster persistence and self-confidence in facing challenges in learning mathematics.

2) METHODS

The approach used in this study is a literature review. This method was chosen to obtain an in-depth understanding of the relationship between mathematical generalization ability and mathematical resilience based on previous research findings. A literature review allows researchers to identify patterns, concepts, and research gaps emerging across related scientific publications (Snyder, 2019). Thus, this study not only compiles existing research but also critically examines it to construct a more comprehensive conceptual understanding.

The data sources for this study consist of national and international peer-reviewed journal articles relevant to the topics of mathematical generalization or mathematical resilience within the context of mathematics education. The selected articles were published in accredited journals, in both Indonesian and English, within the period of 2015–2025 to ensure the relevance and currency of the data (Kitchenham & Charters, 2021).

The analysis stage employed qualitative content analysis to examine each article thoroughly. Each article was reviewed to extract key elements such as conceptual definitions, ability indicators, empirical findings, and the nature of the relationship between mathematical generalization and mathematical resilience. The extracted data were then categorized according to emerging themes, including cognitive aspects, affective aspects, instructional strategies, and implications for higher-order mathematical

thinking. This method of content analysis is considered effective for identifying meaning and patterns within complex literature (Krippendorff, 2018).

Therefore, this approach is expected to provide a comprehensive overview of the relationship between mathematical generalization ability and mathematical resilience, as well as open opportunities for further research in developing instructional strategies for mathematics learning.

3) RESULTS AND DISCUSSION

Results

Based on the results of searching and selecting the literature according to the predetermined criteria, a total of 15 national and international journal articles relevant to the topics of mathematical generalization and mathematical resilience were obtained. The selected articles consist of descriptive studies, experimental research, and qualitative investigations focusing on students' mathematical thinking abilities, particularly in the context of generalization and the affective factors that support it, such as resilience.

The following table presents a summary of the articles included in this literature review.

Table 1: *Summary of Articles*

No	Judul Artikel	Penulis/Tahun	Fokus Penelitian
1	<i>Generalization process by young students</i>	Torres et al., (2021)	To examine the generalization processes of young learners in numerical contexts, including how they identify basic patterns and develop early understanding of mathematical structures.
2	<i>Mathematical generalization in school algebra overview</i>	Palm, (2023)	To review studies on generalization in school algebra, identifying trends, approaches, and

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			common challenges in the development of algebraic thinking.
3	<i>Algebraic generalisation strategies: factors influencing</i>	Lannin et al., (2006)	To analyze the generalization strategies students use in algebraic settings and the factors that influence their choice of strategy and the quality of their generalizations.
4	<i>Early algebra & mathematical generalization</i>	Carraher & Martinez, (2008)	To investigate the relationship between early algebra learning and mathematical generalization, including how informal ideas evolve into formal mathematical understanding.
5	<i>A systematic review: algebraic thinking</i>	Sibgatullin et al., (2022)	To conduct a systematic review of research on

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			algebraic thinking, identifying patterns, key components, and developmental directions of studies related to generalization.
6	<i>Students' mathematical generalization in solving numeracy tasks</i>	Naraswari et al., (2023)	To analyze students' generalization ability in solving numeracy tasks and to identify factors that contribute to their success or difficulties in the generalization process.
7	<i>Developing mathematical resilience</i>	Johnston- wilder & Lee, (2014)	To conceptualize mathematical resilience and develop strategies that teachers can use to foster resilient learning behaviors in mathematics classrooms.
8	<i>Addressing mathematics anxiety</i>	Johnston-wilder et al., (2021)	To explore how building mathematical

	<i>through developing resilience</i>		resilience can reduce mathematics anxiety through the principles of self-determination theory.
9	<i>Resilience in Mathematics Education Research: A Systematic Review of Empirical Studies</i>	Xenofontos & Mouroutsou, (2023)	To systematically review empirical studies on resilience in mathematics education, including definitions, approaches, and implications for teaching and learning.
10	<i>Mathematical resilience, habits of mind, and socio-mathematical norms</i>	Maarif & Fitriani, (2023)	To investigate the role of mathematical resilience, habits of mind, and socio-mathematical norms in shaping interaction patterns and the quality of mathematical learning in secondary schools.

11	<i>Sociomathematical norms, resilience and classroom practice</i>	Maarif & Akbari, (2024)	To analyze the relationship among socio-mathematical norms, resilience, and students' mathematical representation skills in classroom learning practices.
12	<i>Learning obstacles in generalization (number patterns)</i>	Farhatul et al., (2024)	To identify learning obstacles experienced by students when generalizing number patterns and the factors that contribute to these difficulties.
13	<i>Representation & generalization in algebraic reasoning</i>	Uygun et al., (2019)	To examine how visual, symbolic, and verbal representations support generalization in algebraic reasoning through an argumentation-based approach.

14	<i>Meta / mapping studies on algebra & generalisation</i>	Veith et al., (2021)	To map the development of research on algebra and generalization over the past two decades, including pedagogical innovations and emerging research directions.
15	<i>Combining cognitive and affective factors related to mathematics achievement</i>	Hoogmoed et al., (2024)	To integrate cognitive and affective factors in mathematical achievement by analyzing psychological networks among elementary school students.
16	<i>Generalization Strategy of Linear Patterns from Field-Dependent Cognitive Style</i>	Setiawan et al., (2020)	To analyze strategies for generalizing linear patterns based on students' field-dependent cognitive styles, revealing differences in how they identify and organize patterns.

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17	Generalisasi dalam Penalaran Kuantitatif Siswa melalui Pemecahan Masalah Pecahan	Syarifuddin, (2021)	To describe the generalization processes that emerge in students' quantitative reasoning when solving fraction problems.
18	<i>The Mathematical Problem-Solving Ability of Junior High School Students Based on Their Mathematical Resilience</i>	Attami et al., (2020)	To examine students' mathematical problem-solving abilities in relation to their levels of mathematical resilience and how resilience influences their choice of strategies.
19	Riset Keterhubungan: Bagaimana <i>Self- Confidence</i> dan Resiliensi Matematis Mempengaruhi Penalaran dan Kecerdasan Numerik Siswa	Puspita & et al., (2024)	To analyze the interrelationships among self- confidence, mathematical resilience, reasoning, and students' numerical intelligence in mathematics learning.

20	Analisis Kemampuan Penalaran Matematis Siswa dalam Mengerjakan Soal Berbasis AKM Ditinjau dari Resiliensi Matematis	Afifah et al., (2024)	To describe students' mathematical reasoning abilities in solving AKM problems based on their resilience levels, including variations across different resilience categories.
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A synthesis of 20 national and international research articles indicates that the relationship between students' mathematical generalization ability and mathematical resilience can be understood through three major findings: (1) the characteristics and stages of mathematical generalization, (2) the role of resilience as an affective factor supporting cognitive performance, and (3) the integration of both constructs in mathematics learning.

a. Kemampuan Generalisasi Matematis

Research by Torres et al., (2021) found that students' generalization processes develop through concrete, semi-abstract, and symbolic stages, and are strongly influenced by their representational competence. Lannin et al., (2006) serta Mason, (2005) emphasized that the ability to recognize and express general patterns is central to algebraic thinking. A systematic review by Sibgatullin et al., (2022) further supports that algebraic thinking and generalization are closely related to students' metacognitive skills.

Findings from Naraswari et al., (2023) show that many students still struggle to generalize number patterns due to limited conceptual understanding and the lack of exploratory learning opportunities in the classroom. Uygun et al., (2019) revealed that students who frequently use multiple representations (visual, symbolic, and verbal) tend to be more successful in forming general rules. Meanwhile, Veith et al., (2021) mapped the current development of generalization research, noting a shift toward digital learning integration and adaptive symbolic modeling.

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b. Patterns and Stages of Mathematical Generalization

The literature indicates that mathematical generalization is a gradual process evolving from concrete activities to symbolic reasoning. Studies by Torres et al., (2021) dan confirm that students initially identify patterns through visual and numerical representations before expressing them in general forms. Other studies (Sibgatullin et al., 2022; Uygun et al., 2019) identify three common indicators of generalization:

- the ability to recognize patterns and relationships,
- the ability to formulate general rules, and
- the ability to justify or validate the identified structure.

These findings suggest that representation plays a dominant role in successful generalization. Students who routinely work with diagrams, tables, graphs, and symbols develop more systematic generalizations compared to those who rely mainly on procedural operations.

c. Mathematical Resilience

In the affective domain, Johnston-Wilder & Lee, (2024) introduced the concept of mathematical resilience as the ability to persist and recover from difficulties in learning mathematics. Their study emphasizes the importance of a supportive classroom climate that minimizes mathematics anxiety. These findings are reinforced by Johnston-wilder et al., (2021) who show that building students' resilience significantly reduces math anxiety. Research by Maarif & Akbari, (2024) found that social norms and classroom culture influence the development of mathematical resilience; students who participate in collaborative discussions tend to be more confident and persistent when confronting mistakes.

d. The Role of Mathematical Resilience

Across eight articles on resilience, the findings reveal that mathematical resilience is not merely emotional endurance but encompasses three core components:

1. Self-efficacy in facing mathematical challenges,
2. Perseverance when experiencing failure, and

3. A positive attitude toward mistakes as part of the learning process.

Studies by Johnston-Wilder & Lee, (2024) dan Maarif & Fitriani, (2023) highlight that students with high resilience tend to:

- not avoid difficult problems,
- reflect on the strategies they use,
- seek alternative solutions independently, and,
- participate actively in collaborative learning environments.

These findings demonstrate that resilience is not only an emotional trait but also directly influences students' mathematical ways of thinking.

e. Integration of Cognitive and Affective Aspects in Mathematics Learning

The connection between cognitive and affective aspects is clearly reflected in the work of Hoogmoed et al., (2024) which states that mathematical achievement is influenced by the interaction between cognitive abilities (such as logical reasoning and working memory) and affective factors (motivation, attitudes, and confidence). This integration indicates that students' success in mathematical generalization is determined not only by abstract thinking skills but also by the emotional resilience that supports these cognitive processes.

Discussion

a. Generalization as a High-Level Cognitive Activity

Mathematical generalization is a complex process requiring:

- abstract thinking,
- pattern recognition,
- the formulation of general rules, and,
- mathematical justification.

The literature shows that students often face difficulties during the transition from concrete patterns to symbolic representations (Farhatul et al., 2024). These difficulties are often not due solely to cognitive limitations but also to insufficient emotional resilience when encountering new problems. This indicates that affective aspects significantly influence how far students are able to progress in generalizing ideas.

b. Resilience as a Foundation for the Generalization Process

Mathematical resilience provides the affective framework that allows cognitive processes to function optimally. Resilient students dare to explore, accept uncertainty, and persist even when patterns are not immediately visible.

In the context of generalization, resilience functions as:

- a trigger for the courage to try, even without full understanding,
- a pillar of perseverance during pattern testing,
- a motivator for sustained learning, and
- a positive mindset that supports conceptual revision.

Thus, resilience is not merely emotional support it is an integral element of mathematical thinking.

c. The Relationship Between Mathematical Generalization and Resilience

Based on the synthesis of the literature, it can be concluded that generalization ability and mathematical resilience complement each other. The generalization process requires perseverance, reflective thinking, and the willingness to try new patterns, while resilience supplies the affective support that enables students to continue thinking even when faced with errors or failures. Students with high resilience tend to be more patient and persistent in finding patterns, verifying results, and revising their strategies. This aligns with the view of (Johnston-Wilder & Lee, 2024) that resilience is not only emotional endurance but also a learning skill that helps students overcome cognitive challenges.

d. The Role of Affective Aspects in Strengthening Abstract Thinking

The literature indicates that mathematical resilience has a direct relationship with the development of higher-order thinking. (Maarif & Akbari, 2024) assert that students with high resilience are more likely to use reflective approaches when encountering errors. They do not give up easily but instead view mistakes as opportunities to refine their reasoning. This supports Vygotsky's social learning theory, which states that social interaction and emotional support play crucial roles in cognitive development. A learning environment that fosters resilience creates a safe space for students to generalize mathematical ideas without fear of failure.

e. Implications for Mathematics Education

This literature review yields several important implications for educators:

1. Learning approaches should integrate cognitive and affective aspects; teachers must balance challenging exploratory tasks with emotional support that builds confidence.
2. Problem-based learning and reflective discussions stimulate generalization skills while strengthening students' resilience.
3. Assessment of mathematical ability should not only measure final outcomes (cognitive products) but also students' thinking processes and attitudes toward difficulties (resilience indicators).

f. Final Synthesis

Overall, the findings show that mathematical generalization is a manifestation of higher-order thinking that requires deep conceptual understanding, while mathematical resilience serves as the psychological foundation that enables this thinking process to occur consistently. These two constructs have a reciprocal relationship: strong cognitive abilities can enhance confidence and motivation, while strong emotional resilience allows students to maintain focus and persistence until patterns or correct solutions are found.

This literature review concludes that the relationship between mathematical generalization and mathematical resilience is mutually reinforcing. Students with high resilience are more capable of engaging in deep generalization, while successful generalization further enhances their confidence and perseverance in learning mathematics. Therefore, mathematics instruction should be designed

integratively, balancing cognitive training (generalization) and affective development (resilience), so that students not only think logically but also exhibit emotional strength when facing learning challenges.

4) CONCLUSIONS

Based on the literature review conducted on 15 national and international scientific articles, several conclusions can be drawn as follows:

1. Mathematical generalization ability is an essential cognitive skill in higher-order mathematical thinking, involving the activities of recognizing patterns, constructing general forms, and reasoning abstractly. This ability serves as a foundation for students' mastery of algebraic concepts and logical reasoning.
2. Mathematical resilience is an affective ability that reflects students' endurance, perseverance, and self-confidence when facing difficulties in learning mathematics. Resilience plays a significant role in maintaining motivation and persistence throughout the learning process.
3. The relationship between mathematical generalization and mathematical resilience is mutually reinforcing. The generalization process requires perseverance and a willingness to persist qualities rooted in resilience while success in generalization further enhances students' confidence and positive attitudes toward mathematics.
4. The implication of this relationship is the need for integrative mathematics instruction that combines both cognitive and affective aspects. Teachers must create a learning environment that supports the exploration of ideas and provides opportunities for students to learn from mistakes, enabling them not only to think logically but also to develop emotional resilience when facing learning challenges.

This study is expected to serve as a theoretical foundation for future research that empirically examines the relationship between mathematical generalization and mathematical resilience, as well as for the development of instructional materials that systematically integrate these two aspects.

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