

# Strengthening mathematical resilience through the implementation of self-directed learning models

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## Abstract

This study examines the role of self-directed learning (SDL) in strengthening mathematics resilience among students. Mathematics resilience is crucial for students to persist and maintain motivation in facing mathematics challenges. This study employed a literature review approach, analyzing empirical studies from national and international sources published between 2021 and 2025. This study employed a systematic literature review. Through this method, researchers collected, reviewed, and analyzed various written sources relevant to the topic of self-directed learning in strengthening mathematics resilience. The primary data sources in this study came from relevant national and international journal articles published within the last five years (2021–2025) obtained from Google Scholar, ERIC, Scopus, and DOAJ. The analysis technique used in this research is literature triangulation. The findings indicate that SDL enhances student autonomy, metacognitive skills, and problem-solving abilities, which are essential components of mathematics resilience. National studies emphasized the practical implementation of SDL through modules, problem-based learning, and group discussions, while international research focused on the conceptual and emotional aspects of resilience, highlighting the role of motivation and emotion regulation. This study revealed that SDL, particularly when integrated with digital tools, fosters a collaborative learning environment that further supports resilience. The results indicate that SDL is an effective strategy for developing both the cognitive and affective aspects of mathematics resilience.

## Keywords

Mathematical resilience, Self-directed learning models, Literature review

## Introduction

Mathematics is a crucial discipline for developing critical, logical, and systematic thinking skills. Yet, in many classrooms it is still experienced by students as difficult and anxiety-inducing often because learning is dominated by teacher-centered procedures, a strong focus on getting the “right answer,” and limited opportunities for students to explore

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strategies, make mistakes safely, and reflect on their thinking. These conditions can become root causes of low mathematical resilience, where students quickly lose confidence, avoid challenges, and give up after experiencing failure. Although the importance of resilience is widely acknowledged, there remains a gap in learning models that intentionally build students' persistence and motivation through structured independence in learning. This research addresses that gap by proposing the Self-Directed Learning (SDL) model as a solution, as SDL trains students to set goals, plan and monitor their learning, seek appropriate resources, and evaluate their strategies so obstacles in mathematics are treated as feedback for improvement rather than reasons to stop learning [1]. Mathematical resilience plays a crucial role in developing students' self-confidence, problem-solving skills, and sustained interest in mathematics [2].

Several studies confirm that mathematical resilience is not only related to cognitive abilities but also involves affective and social aspects. Pulungan [3] found that emotional factors such as motivation, emotional regulation, and social support significantly influence students' resilience in facing the challenges of learning mathematics. Therefore, to strengthen mathematical resilience, learning strategies need to be designed so that students can develop cognitive skills while managing their affective aspects.

One approach considered effective in this context is self-directed learning (SDL). SDL is a learning model that emphasizes student independence in planning, monitoring, and evaluating their learning process. The implementation of SDL allows students to set learning goals, choose appropriate strategies, and reflect on their achievements. This aligns with the findings of Sofitri and Nugraheni [4] who stated that SDL improves students' self-regulation and metacognitive skills, two important aspects in building mathematical resilience.

Furthermore, SDL can be applied in various forms, such as problem-based learning, independent modules, and project-based learning. Kuncoro and Juandi [2] emphasized that problem-based learning can encourage students to view challenges as learning opportunities, not obstacles. Similarly, research by Haryani [5] showed that the use of SDL-based modules can improve problem-solving skills while strengthening students' resilience in facing complex problems.

The collaborative dimension of SDL also contributes to strengthening mathematical resilience. Through group work or e-cooperative learning, students can share strategies, provide emotional support, and build self-confidence. Pulungan [3] and Tampa [6] emphasized that this type of collaboration helps reduce anxiety and increase student learning motivation. In fact, Kuisma dan Ratinen [7] found in their research during the COVID-19 pandemic that technology-based SDL with a collaborative approach effectively supports mathematical resilience in online learning.

Based on the above description, the application of Self-Directed Learning (SDL) in mathematics learning has strong potential to strengthen students' mathematical

resilience. Although previous studies have generally reported a positive relationship between SDL and resilience, most of them tend to discuss the relationship in a fragmented way limited to certain contexts, education levels, or specific indicators so the overall picture of how SDL contributes to resilience is not yet mapped systematically. In contrast to earlier research, this study offers a more comprehensive conceptual contribution by synthesizing and mapping both national and international literature to identify research trends, dominant themes, and underexplored areas related to SDL and mathematical resilience. To strengthen this contribution, this article also employs bibliometric visualization to show the structure of the research landscape and the connections among key concepts. Therefore, this article aims to explain how the implementation of SDL can strengthen mathematical resilience through independent learning, the development of metacognitive skills, and collaborative learning, while also providing a structured map of the evidence base that can guide future research and classroom implementation.

## Method

This article uses a literature review approach which aims to critically examine various studies related to mathematical resilience and the application of the self-directed learning (SDL) model in mathematics learning [8]. This approach was chosen because it provides a comprehensive overview of trends, findings, and academic contributions from previous research.

Data sources were obtained from relevant national and international journal articles published within the last five years (2021–2025). This timeframe was chosen to ensure the novelty and relevance of the study. Furthermore, several classic references considered fundamental, such as Knowles [9] and Garrison [10], were also used as a conceptual basis for understanding SDL.

Articles and literature sources were searched through credible online databases, such as Google Scholar, ERIC, Scopus, and DOAJ. Keywords used in the search included mathematical resilience, self-directed learning, mathematics education, and problem-solving skills. After the search process, relevant sources were then selected based on the following inclusion criteria: (1) articles published in reputable journals (indexed by Sinta, DOAJ, Scopus, or equivalent); (2) articles focused on mathematical resilience, SDL, or both; and (3) articles published between 2021 and 2025, except for classical sources used as theoretical basis.

The analysis was conducted through three main stages: (1) identification, which involves selecting articles according to the research topic; (2) categorization, which involves grouping articles based on the focus of the findings, such as the cognitive, affective, and social aspects of mathematical resilience, as well as the application of SDL in various learning strategies; and (3) synthesis, which involves compiling the results of the literature review in an integrated manner to build conceptual arguments. This synthesis

aims to identify the relationship between SDL and mathematical resilience and to outline the theoretical and practical implications for mathematics education.

To maintain the validity of the study, the literature was selected by considering the quality and relevance of the sources. The selected articles were from peer-reviewed journals with good academic reputations. Furthermore, literature triangulation was conducted by comparing research results from various contexts (national and international) to obtain a more comprehensive and objective picture [11].

## Results

To obtain a comprehensive overview of the relationship between self-directed learning (SDL) and mathematical resilience, an in-depth review of several national and international studies was conducted. This analysis is not only descriptive but also comparative, aiming to highlight the similarities, differences, and contributions of the findings in the two contexts. National research generally emphasizes the practical implementation of SDL in the classroom, its impact on problem-solving skills, and the development of mathematical resilience instruments. Meanwhile, international research examines SDL and mathematical resilience more broadly within a conceptual framework, focusing on psychological and motivational aspects, as well as the integration of digital technology.

To facilitate mapping the findings, the results of the literature review are presented in a table comparing national and international research on four main aspects: (1) mathematical resilience as an affective and cognitive competency, (2) the role of SDL in independent learning, (3) collaboration in SDL as a factor strengthening resilience, and (4) the integration of SDL in the digital age. The following table presents a synthesis of findings from both contexts, while also providing a comparative analysis that strengthens this article's conceptual argument.

**Table 1** presents a comparison of national and international research findings on mathematical resilience and the application of self-directed learning (SDL). The table clearly shows that national research focuses more on practical implementation aspects in the classroom, while international research emphasizes conceptual, affective, and digital dimensions. Despite their different focuses, both converge on a key common thread: mathematical resilience and SDL as central themes.

To strengthen the analysis of the table, a simple bibliometric mapping was conducted based on key keywords frequently appearing in the research. This bibliometric visualization provides an overview of the relationships between research themes and groups keywords into four broad clusters: cognitive, affective, collaborative, and digital. Thus, the resulting image not only complements the information in the table but also demonstrates how national and international research developments complement each other and open up opportunities for future integration.

Table 1. Research study

Study Aspects	National Research Findings (Sinta)	International Research Findings (Reputable)	Synthesis of Findings
Mathematical Resilience	<ol style="list-style-type: none"> <li>1. Mathematical resilience improves students' problem-solving abilities [1].</li> <li>2. Resilience has a positive effect on logical mathematical thinking [13].</li> <li>3. The mathematical resilience instrument has been tested for validity using the Rasch Model [15].</li> <li>4. Resilience is important for prospective mathematics teachers in problem-based learning [17].</li> <li>5. Affective factors such as motivation play a role in resilience in mathematics learning [19].</li> </ol>	<ol style="list-style-type: none"> <li>1. Resilience is the ability to positively adapt to difficulties in learning mathematics [12].</li> <li>2. Emotions and motivation influence problem-solving success [14].</li> <li>3. Conceptualization of mathematical resilience within an educational psychology framework [16].</li> <li>4. Children's anxiety profiles are related to protective factors for resilience [18].</li> <li>5. Mathematical literacy in resilient students can be predicted using an algorithmic model [20].</li> </ol>	National emphasizes the influence of resilience on cognitive achievement, while international emphasizes the emotional, psychological, and conceptual aspects of resilience.
SDL in Independent Learning	<ol style="list-style-type: none"> <li>1. SDL encourages independent learning through independent modules [4].</li> <li>2. SDL improves students' self-regulation in mathematics learning [3].</li> <li>3. SDL is relevant when applied to problem-based learning [2].</li> <li>4. SDL implementation strengthens students' metacognitive skills [5].</li> <li>5. SDL has a positive impact on increasing students' learning motivation [1].</li> </ol>	<ol style="list-style-type: none"> <li>1. Self-Regulated Learning (SDL) is a comprehensive model that integrates self-regulation and reflection [10].</li> <li>2. Self-Regulated Learning (SDL) is closely related to self-regulated learning [21].</li> <li>3. Self-Regulated Learning (SDL) enhances independence and responsibility for learning in higher education [22].</li> <li>4. Self-Guided Learning (SDL) is effective for marginalized STEM groups [23].</li> <li>5. Self-Regulated Learning (SDL) based on self-learning tools effectively improves academic skills [24].</li> </ol>	National focuses more on practical implementation in the classroom, while international studies examine SDL as a broader conceptual framework and model.
Collaboration in SDL	<ol style="list-style-type: none"> <li>1. Group-based SDL increases students' emotional support (Pulungan et al., 2022).</li> <li>2. Collaboration in problem-solving reduces learning anxiety (Fitriani et al., 2023).</li> <li>3. Collaborative discussion activities strengthen students' social skills (Kuncoro &amp; Juandi, 2023).</li> <li>4. Collaboration fosters student resilience in PBL (Haryani et al., 2025).</li> <li>5. Peer support effectively builds mathematics motivation (Sofitri &amp; Nugraheni, 2024).</li> </ol>	<ol style="list-style-type: none"> <li>1. Collaboration reduces math anxiety and increases self-confidence [25].</li> <li>2. Learning communities build academic resilience [26].</li> <li>3. Peer learning strengthens problem-solving strategies [21].</li> <li>4. Online collaboration is effective in resilient mathematics learning [27].</li> <li>5. Social support is a protective factor for academic resilience [18].</li> </ol>	National focuses on classroom pedagogy, international on psychosocial aspects and learning communities.
SDL in the Digital Age	<ol style="list-style-type: none"> <li>1. The use of an SDL-based LMS increases student motivation and resilience [6].</li> </ol>	<ol style="list-style-type: none"> <li>1. Technology-based SDL increases learning flexibility [28].</li> </ol>	Nationally, the focus is still on

Study Aspects	National Research Findings (Sinta)	International Research Findings (Reputable)	Synthesis of Findings
	2. SDL-based e-learning supports resilience during the pandemic [29]. 3. SDL digital modules improve students' mathematical literacy [1]. 4. The integration of technology with SDL expands access to independent learning [5]. 5. Digital SDL is relevant for distance learning [3].	2. E-cooperative learning supports resilience in online learning [27]. 3. Digital SDL increases student self-efficacy [22]. 4. The use of interactive modules strengthens resilience in STEM learning [23]. 5. The integration of digital technology strengthens students' independent reflection [24].	utilizing simple digital modules, while internationally, it has explored the integration of SDL with complex digital technologies.

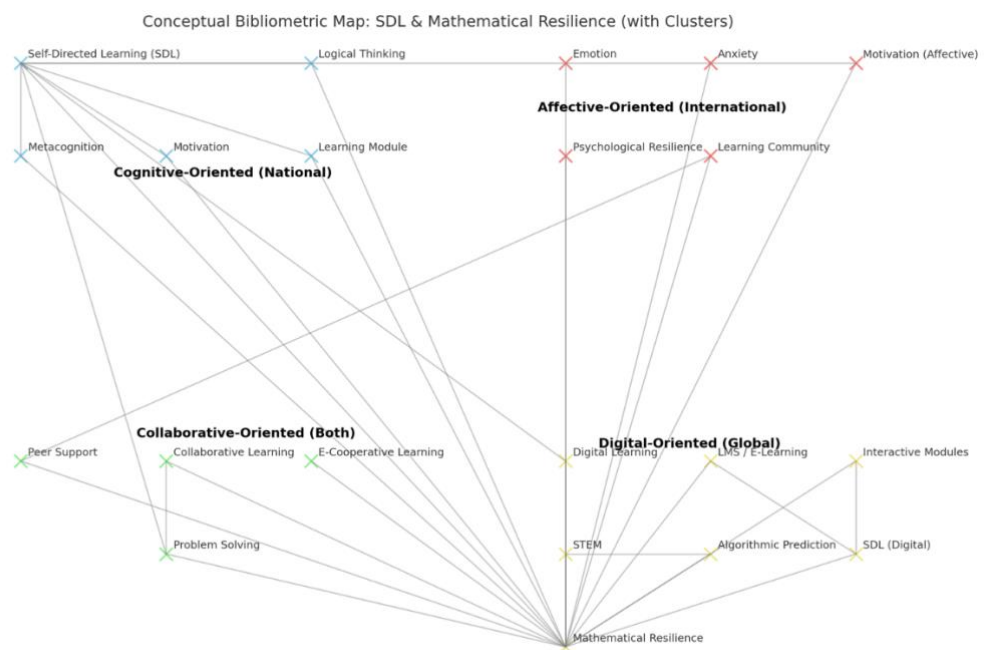


Figure 1. Vos Viewer bibliometric output

Figure 1 shows a bibliometric conceptual map that charts the relationship between key keywords in the study of self-directed learning (SDL) and mathematical resilience. This visualization yields four main interconnected clusters:

First, the Cognitive-Oriented Cluster (National) shown in light blue, contains topics such as problem solving, logical thinking, metacognition, and the use of learning modules. This cluster emphasizes how SDL is practically implemented to improve students' cognitive achievement in mathematics.

Second, the Affective-Oriented Cluster (International) marked in pink, contains topics such as emotion, anxiety, psychological resilience, and learning community. This cluster focuses on the psychosocial dimension of mathematical resilience, namely how motivational and emotional factors play a crucial role in shaping students' resilience in the face of learning difficulties.

Third, the Collaborative-Oriented Cluster (National & International) – shown in light green, contains peer support, collaborative learning, and e-cooperative learning. This cluster indicates that, in both national and international contexts, collaboration has been shown to be a crucial factor in building resilience, as it provides social support and reduces math anxiety.

Fourth, the Digital-Oriented (Global) Cluster marked in yellow, contains topics such as digital learning, LMS/e-learning, interactive modules, STEM, and algorithmic prediction. This cluster demonstrates the global trend of integrating SDL with digital technology, which not only expands access to independent learning but also supports personalized learning and mathematical literacy in the digital age.

Overall, this bibliometric map shows that national research emphasizes cognitive aspects and practical implementation, while international research focuses more on affective aspects and digital integration. However, all four clusters intersect at the central nodes of Mathematical Resilience and Self-Directed Learning (SDL), demonstrating that these two are core themes connecting all research developments.

## Discussion

The study results show that mathematical resilience is understood differently by both national and international research. National research focuses more on the relationship between resilience and cognitive outcomes, such as problem-solving and logical thinking skills [1], [13]. International research, on the other hand, defines resilience within a broader framework, encompassing motivational, emotional, and coping strategies [12], [14]. These differing perspectives have two implications. First, national research still needs to develop resilience instruments that measure not only cognitive impacts but also affective dimensions of students. Second, conceptual approaches from international research can serve as a foundation for enriching learning interventions in Indonesia, particularly those that emphasize the balance between cognitive and affective aspects in mathematics learning.

Furthermore, SDL has been shown to significantly contribute to the development of mathematical resilience. National research [4], [5] confirms that self-directed learning modules and problem-based learning encourage students to be more independent, reflective, and organized in their learning. This aligns with international research [10], [21], which views SDL as a comprehensive framework integrating self-regulation, motivation, and reflection on learning. This comparison indicates that national research tends to be pragmatic, focusing on classroom implementation, while international research is more theoretical. This means that SDL practice in Indonesia still requires a stronger theoretical foundation so that it is not merely oriented towards technical implementation but can also be integrated with established conceptual frameworks at the global level.

Furthermore, both national and international research emphasize the importance of collaboration in SDL. In Indonesia, collaboration is often associated with strengthening emotional support between students and increasing learning motivation [3]. Meanwhile, international studies emphasize that collaboration forms a learning community that can reduce math anxiety and increase courage in facing challenges [25]. This difference indicates that national studies focus more on pedagogical and applied aspects in the classroom, while international studies emphasize psychosocial aspects and the formation of a learning culture. Thus, research in Indonesia can be expanded into the psychosocial realm, for example by examining how peer support and digital learning communities influence mathematical resilience.

The COVID-19 pandemic has accelerated the integration of technology into mathematics learning. National research [6], [29] still emphasizes the use of electronic modules and Learning Management Systems (LMS) to support SDL. In contrast, international research has further explored interactive and adaptive technology-based SDL, such as e-cooperative learning [27] and algorithm-based learning models to predict mathematical literacy [20]. This gap indicates that Indonesia is still at the early stages of adapting to the implementation of digital SDL. Practical implications include the need to develop more innovative and interactive technology-based SDL models, for example, utilizing learning analytics, gamification, or artificial intelligence.

The literature review shows a consistent pattern between national and international research regarding the role of self-directed learning (SDL) in strengthening mathematical resilience. National research emphasizes practical implementation in the classroom, such as the use of self-directed modules, problem-based learning, and group discussions, which have been shown to increase student learning independence and resilience. Meanwhile, international research places greater emphasis on conceptual and psychosocial frameworks, highlighting the role of emotions, motivation, peer support, and technology integration in strengthening resilience.

Comparatively, national studies provide rich empirical evidence on field practices, but are often limited to cognitive aspects and learning outcomes. Conversely, international studies offer a broader perspective on how mathematical resilience is formed through a combination of cognitive, affective, social, and digital factors. Thus, these two research domains complement each other: national studies play a role in providing evidence-based practice, while international studies provide a theoretical framework to deepen understanding of the phenomenon.

This synthesis emphasizes the importance of integrating implementation practices in Indonesia with global conceptual frameworks. Mathematics educators can adopt a more comprehensive SDL approach, not only emphasize student learning independence but also consider motivational aspects, social support, and the use of digital technology. Furthermore, further research in Indonesia needs to be directed at developing technology-based SDL models and comprehensive mathematical resilience

measurement instruments to align with global developments and the challenges of 21st-century learning.

## Conclusion

This literature review confirms that the implementation of the self-directed learning (SDL) model significantly contributes to strengthening students' mathematical resilience. National research tends to emphasize practical implementation aspects in the classroom, such as the use of self-paced modules, problem-based learning, and group discussions, which impact learning independence and problem-solving skills. In contrast, international research emphasizes a broader conceptual framework, encompassing affective, motivational, and psychosocial aspects, as well as the integration of digital technology.

The synthesis of these two perspectives indicates that effective mathematics learning focuses not only on cognitive achievement but also on students' affective and social dimensions. Therefore, the implementation of SDL in Indonesia needs to be continuously developed through technology-based innovation and strengthening mathematical resilience measurement instruments. This way, students will not only be able to master mathematical skills but also develop resilience, motivation, and courage in facing the challenges of 21st-century learning.

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