




# How does self-regulated learning affect students' mathematics anxiety?

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## ABSTRACT

Math anxiety can significantly impair student learning outcomes. This is often due to a lack of self-regulated learning (SRL), leading to a reliance on external guidance. This systematic literature review aimed to increase existing knowledge on the role of SRL in reducing students' mathematics anxiety and to assess its impact on improving learning outcomes. Using the PRISMA procedure, 28 studies were selected to explore the relationship between SRL and math anxiety. Findings showed that higher levels of SRL were associated with reduced math anxiety, while lower levels were associated with increased math anxiety. This study confirms the importance of educators implementing strategies that promote SRL to decrease math anxiety and improve student performance.

**Keywords:** self-regulated learning, mathematics anxiety, systematic literature review

## INTRODUCTION

Mathematics education plays a crucial role in shaping students' understanding and achievement. However, many students experience anxiety when learning mathematics (Khasawneh et al., 2021). This anxiety represents a significant challenge, as it can hinder students' ability to grasp concepts and approach mathematical tasks with confidence. Consequently, it serves as a major barrier to achieving optimal learning outcomes (Ramirez et al., 2018).

To address this pressing issue of mathematics anxiety, it is essential to understand the factors influencing it. Recent educational research has shifted focus to the role of self-regulated learning (SRL). This shift underscores the importance of investigating how effective learning strategies can mitigate anxiety and enhance student performance in mathematics. SRL refers to the process of developing an individual's ability to understand and control their learning, essentially learning how to learn (Taranto & Buchanan, 2020). Empirical studies indicate that students with high levels of SRL tend to be more persistent and diligent in their studies compared to those with lower levels.

Despite numerous previous studies, a comprehensive systematic literature review analyzing the relationship between SRL and anxiety in the context of mathematics learning is still needed. This review aims to provide a deeper understanding of the role of SRL in alleviating the anxiety that students face, thereby addressing the core issue of mathematics anxiety.

By clarifying this relationship, educators and researchers can develop targeted learning strategies that effectively reduce anxiety while enhancing students' SRL skills. This understanding will ultimately contribute positively to students' comprehension and achievement in mathematics. This article will outline the steps taken in the systematic literature review, analyze important findings from relevant studies, and discuss practical implications and suggestions for future research.

## METHODS

To explain the relationship between SRL and math anxiety in learning mathematics, the literature review method was used. This literature review method involves a process of collecting, reviewing, and analyzing relevant literature or sources related to the research topic. This method includes identification, collection, assessment, and synthesis of published literature. Through this

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The article is a component of a master's thesis in mathematics education authored by the first author from Yogyakarta State University in Indonesia.

**Table 1.** Research questions

No	Research question	Motivation
1	How many and what is the distribution of journals that discuss SRL and math anxiety?	Identifying the number and distribution of journals that discuss SRL and math anxiety
2	What type of research is most effective in exploring the relationship between SRL and math anxiety?	Identifying the most effective type of research to explore the relationship between SRL and math anxiety.
3	Who are the most relevant research subjects to obtain representative data regarding SRL and math anxiety?	Identifying the most relevant research subjects to obtain representative data regarding SRL and math anxiety.
4	What are the most valid and reliable instruments to measure SRL and math anxiety?	Identifying the most valid and reliable instruments to measure SRL and math anxiety.
5	What is the most appropriate method of analysis to use in analyzing data obtained regarding SRL and math anxiety?	Identifying the most appropriate method of analysis to use in analyzing data obtained regarding SRL and math anxiety.
6	What is the main objective of this research in understanding the relationship between SRL and math anxiety?	The main objective of this research in understand the relationship between SRL and math anxiety.
7	What are the key findings of this research regarding SRL and math anxiety, and how can these findings be interpreted within the context of existing theory?	Identifying the key findings of this research regarding SRL and math anxiety, and how these findings can be interpreted within the context of existing theory.

Note. Modified from Latifah (2020)

method, the research can gather comprehensive and in-depth information to support a better understanding of the topic under study (**Appendix A** and **Appendix B**).

### Research Questions

Here are the research questions that have been determined in this study, modified from Latifah and Ritonga (2020) (**Table 1**).

### Research Design

This research adopts a content analysis approach (Fauzi & Pradipta, 2018), focusing on findings from various studies published in national and international journals. The research method applied is similar to the research conducted by Fauzi and Pradipta (2018), with some adjustments made.

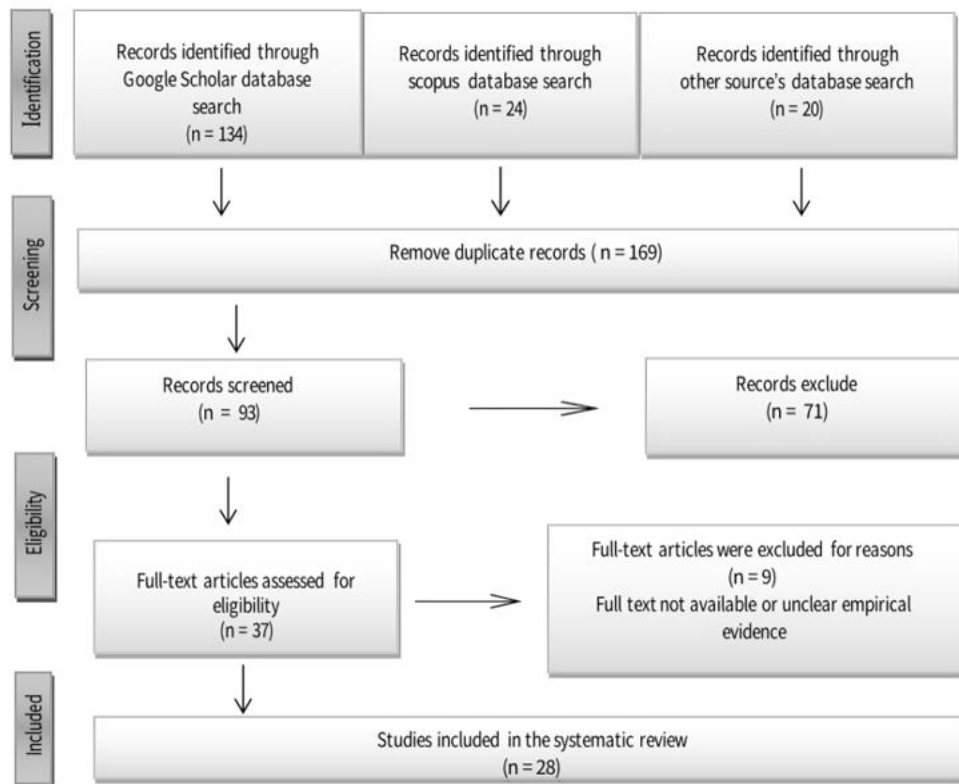
### Data Sources

The literature review allows researchers to conduct a comprehensive literature search through academic databases and trusted sources, using keywords relevant to the research topic. The keywords used are “Self-regulated learning” OR “Self-directed learning” OR “Autonomous learning” OR “Independent learning” OR “Learner autonomy” OR “Self-managed learning” OR “Self-regulation in education” OR “Personal learning management” OR “Cognitive self-regulation” OR “Student self-regulation” OR “Self-guided learning” OR “Self-determined learning” OR “Self-monitoring” OR “Self-control in learning” OR “Learning autonomy” OR “Active learning strategies” OR “Self-planned learning” OR “Self-regulated academic behavior” OR “Learning self-management” OR “Self-motivation in learning” OR “Self-governed learning” OR “Self-driven study habits” OR “Student learning strategies” OR “Metacognitive regulation” OR “Self-regulation of behavior” OR “Self-discipline in learning” OR “Self-reflective learning” OR “Strategic learning” OR “Self-organized learning” OR “Student-driven learning” OR “Learning self-regulation strategies” OR “Math anxiety” OR “Mathematics anxiety” OR “Math fear” OR “Numeracy anxiety” OR “Math-related stress” OR “Math phobia” OR “Fear of math” OR “Anxiety towards mathematics” OR “Fear of numbers” OR “Numerical anxiety” OR “Quantitative anxiety” OR “Mathematical apprehension” OR “Math-related anxiety” OR “Math performance anxiety” OR “Test anxiety in math” OR “Math evaluation stress” OR “Fear of solving math problems” OR “Anxiety in math tests” OR “Math avoidance” OR “Discomfort with mathematics” OR “Negative attitude towards math” OR “Math learning anxiety” OR “Mathematical test anxiety” OR “Fear of arithmetic” OR “Stress related to math” OR “Performance anxiety in mathematics” OR “Math-induced stress” OR “Panic in math situations” OR “Worry in mathematical tasks” OR “High anxiety in math” OR “Numerical performance fear” OR “Mathematical stress disorder”. Articles are selectively chosen and analyzed according to established criteria. In the literature review research, several steps in literature selection refer to the PRISMA model (Page et al., 2021):

1. **Identification:** This step involves searching for as much literature as possible from various databases relevant to the chosen research topic.
2. **Screening:** This step deals with the screening or selection process of the collected literature. Articles that are irrelevant or do not meet the predefined inclusion criteria are removed.
3. **Quality evaluation:** After screening, all selected literature findings will be further analyzed and evaluated in terms of the quality of the research methodology used.
4. **Inclusion:** The final step is to include the selected literature in a data tabulation. The findings from the literature will be the basis for answering the research questions that have been previously set.

By following these steps, the literature review research can provide a comprehensive and structured overview of the relationship between SRL and mathematics anxiety in mathematics learning.

The literature review focused on mathematics and addressed SRL and mathematics anxiety, using sources published in national and international journals between 2018-2024. Articles outside these criteria were excluded. The review process included eliminating duplicates, evaluating the relevance of titles and abstracts, and ensuring full-text availability.



**Figure 1.** Flow diagram (Page et al., 2021)

Data collection involved searching databases such as Google Scholar, Scopus, and PubMed for articles published during the specified period. Rigorous selection criteria were applied to ensure relevance, followed by screening titles, abstracts, and full texts. Duplicates and irrelevant studies were removed, retaining only the most relevant sources (Figure 1).

The data collection process for this systematic review began with identification, where initial data was gathered from three database sources: Google Scholar, Scopus, and other sources. A total of 178 articles were found for further analysis. Next, in the screening stage, duplicate articles were removed, leaving 93 articles for further filtering based on their titles and abstracts to determine their relevance to the research topic.

Following that, in the eligibility assessment stage, 37 articles were selected for in-depth analysis by reviewing their full texts. From this process, 9 articles were excluded due to the lack of full texts or unclear empirical evidence. Finally, in the inclusion stage, 28 articles that met all eligibility criteria were included in the systematic review. This process ensures that only relevant articles that meet stringent criteria are included in the final analysis.

### Research Instruments

Content analysis guidelines are used as instruments in this research, covering various observed aspects (see Table 2). There are five main aspects analyzed, including

- (1) the number of publications per year,
- (2) types of research,
- (3) research subjects,
- (4) data collection instruments, and
- (5) data analysis methods.

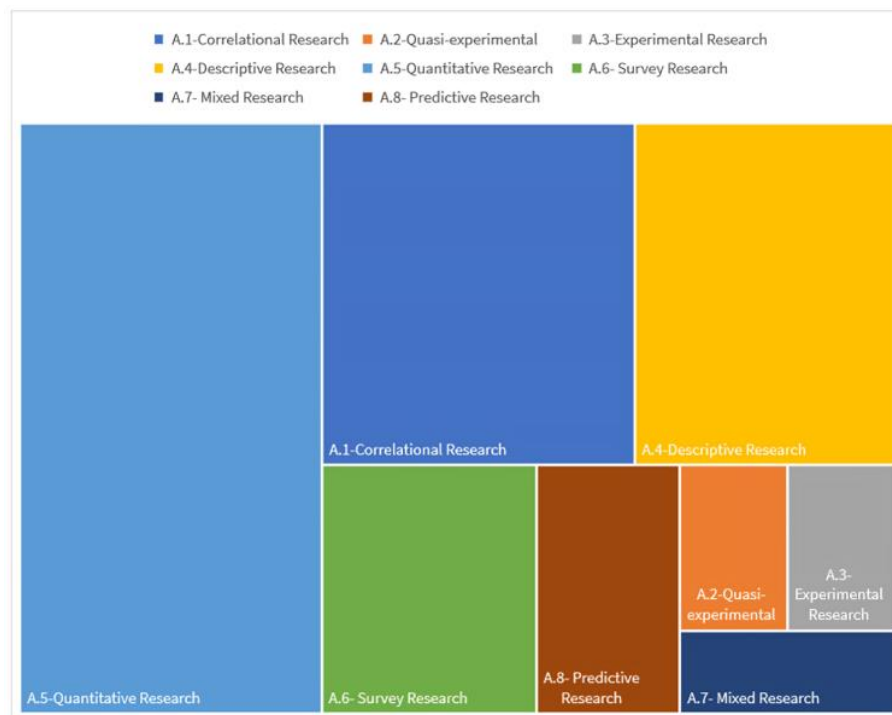
The determination of categories for aspect (1) is not conducted because there are no previous studies that can be used as a reference, so the categories are determined during a content analysis of several articles. However, categories for aspects (2), (3), (4), and (5) have been established before data collection. Table 2 shows the categories adapted and modified from previous research (Fauzi & Pradipta, 2018).

### Data Analysis

Each article is categorized according to the previously defined aspects. Classification is based on the information provided in the abstract, methods, and research results sections. Data is collected and then presented in the form of bar charts to clearly and comprehensively visualize the results (Fauzi & Pradipta, 2018).

**Table 2.** Research instruments

Type	Instrument	Instrument
Type of research	A.1-Correlational research	A.5-Quantitative research
	A.2-Quasi-experimental	A.6-Survey research
	A.3-Experimental research	A.7-Mixed research
	A.4-Descriptive research	A.8-Predictive research
Subject of research	B.1-Elementary school	B.3-Senior high school
	B.2-Junior high school	B.4-University students
Data collection instruments	C.1-Questionnaire	C.4-Rating scale
	C.2-Observation	C.5-Metacognitive
	C.3-Test	
Analysis method	D.1-SEM	D.6-Chi-square
	D.2-Correlation	D.7-Pant analysis
	D.3-Descriptive analysis	D.8-ANOVA
	D.4-Regression	D.9-MANOVA
	D.5-t-test	D.10-Non-parametric statistics

**Figure 2.** Types of research used in journals (Source: Authors' own elaboration)

## RESULTS

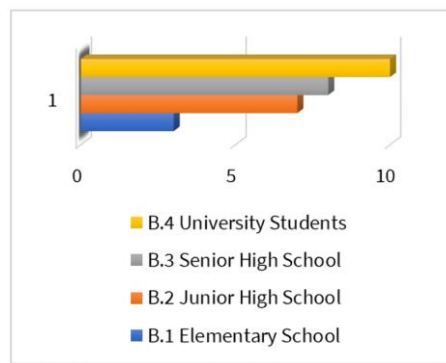
### Distribution of Studied Publications by Year

The number of published articles is an indicator of how frequently research is conducted within a certain period. As seen from the graph attached in **Figure 1**, articles reviewing SRL and mathematics anxiety have been available since 2017. There is no specific shift pattern in the number of publications each year. However, based on the data in **Figure 1**, there has been a significant increase in publications since 2021 compared to previous years. Although there was a decrease in 2022, the trend of increasing publications on SRL and mathematics anxiety indicates ongoing research, showing that the issue still exists and needs to be addressed.

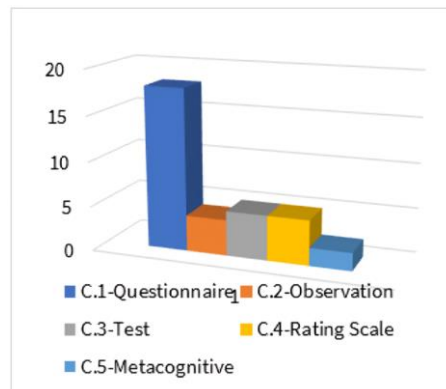
Many studies are conducted in response to common problems often encountered by researchers. One of the major concerns is the low level of SRL and high mathematics anxiety among students. Therefore, conducting research is considered the most effective method to address and resolve these issues. Through research, researchers can identify the most effective learning designs or media to develop confidence and reduce students' mathematics anxiety optimally. The more research conducted to investigate these issues, the greater the positive impact on educational development in Indonesia.

### Types of Research

The research type and design chosen to determine the study's focus. Based on **Figure 2**, quantitative research is the most commonly used design by researchers investigating these issues. This type of research has the advantage of systematically collecting and analyzing measurable and verifiable data. However, other types of research can also be used for future studies.



**Figure 3.** Research subjects in journals (Source: Authors' own elaboration)



**Figure 4.** Research instruments used in journals (Source: Authors' own elaboration)

### Research Subjects

In conducting research, researchers require subjects to test their hypotheses. Based on the results depicted in **Figure 3**, the most commonly chosen research subjects are middle school students. The next most frequently included subjects are higher education students, followed by high school students.

The subjects used in SRL, and mathematics anxiety research are very diverse, ranging from elementary, middle, and high school students to university students.

### Research Instruments

In the research process, researchers need instruments to help collect data. In the context of measuring students' SRL and mathematics anxiety, various instruments have been developed by previous researchers. Based on the information in **Figure 4**, it is concluded that questionnaires are the most frequently used instruments to collect data related to research.

However, other instruments are also recommended for this type of research, such as using direct interviews. Interviews can explore SRL and mathematics anxiety in depth.

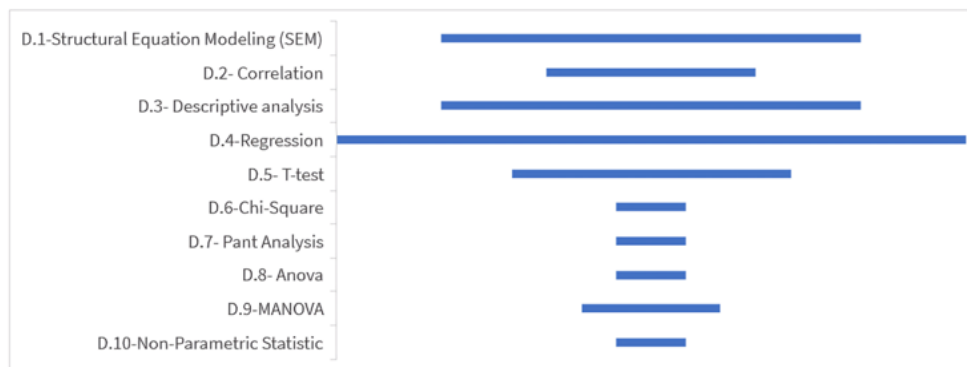
### Analysis Methods

The most commonly used data analysis method in reviewed journals is regression analysis. Regression analysis helps determine whether there is a linear relationship between the dependent and independent variables. Using regression analysis, one can measure the strength and direction of the relationship between these variables. However, many other data analysis methods are also used to examine the relationship between SRL and students' mathematics anxiety (**Figure 5**).

## DISCUSSION

### Frequency of Publications by Year

The number of publications on SRL and math anxiety showed significant fluctuations from 2018 to 2024, reflecting the importance of this topic in academic research. In 2018, there were only 2 publications (Roick & Ringeisen, 2018; Vahidi et al., 2018), but this number increased to 3 in 2019 (Musso et al., 2019; Singh et al., 2019; Thamrin et al., 2018) and 4 in 2020 (Gabriel et al., 2020; Herawati et al., 2021; Tashtoush et al., 2020, 2022). A sharper increase occurred in 2021 with 6 publications indicating greater attention to this issue (Delima & Cahyawati, 2021; Dirgantoro & Soesanto, 2021; Duru & Okeke, 2021; Hutt et al., 2021; Marticion, 2021; Rayoan & Ludji, 2021). Although there was a decrease to 4 publications in 2022 (Erita et al., 2022; Fajri & Amir, 2022; Ghahremani et al., 2022; Rican et al., 2022), interest in this topic peaked in 2023 with 7 (Andres et al., 2023; Atsnan et al., 2018; Balali et al., 2023; Cahyawati et al., 2023; Gürsel et al., 2023; Siregar et al., 2023; Wang, 2023). Although in 2024 the number of



**Figure 5.** Data analysis methods used in journals (Source: Authors' own elaboration)

publications decreased to 2 (Delima et al., 2024; Priharvian et al., 2024), this was due to this study being conducted in early May 2024. These fluctuations suggest that although attention to SRL and math anxiety has had its ups and downs, the importance of research and attention to these topics should not be overlooked due to their significant impact on students' learning and well-being (Dowker et al., 2016; Gabriel et al., 2020). If attention to these two issues is neglected, many students will continue to experience math anxiety each year, which can negatively impact their academic and emotional development. By understanding and addressing both issues, educators can design more effective interventions to support students, thereby improving their learning outcomes and overall well-being.

### Types of Research in Publications Studied

The type of research used in journals on anxiety and SRL varies, with quantitative research being the most dominant, with 10 publications. Correlational research was also widely used, with 6 publications. Descriptive research followed with 5 publications, while survey research accounted for 3 publications. Other types of research such as predictive were used in 2 publications, while quasi-experimental, experimental, and mixed research were only recorded in 1 publication each. This shows that quantitative and correlational approaches are most commonly used to examine the relationship between anxiety and SRL.

Quantitative research is highly recommended in the study of anxiety and SRL as this approach allows researchers to measure variables objectively and analyze data using robust statistical techniques. With the largest number of publications, quantitative research has proven to be effective in identifying relationships and patterns between anxiety and SRL. In addition, quantitative research can provide data that can be generalized to a wider population, so the results can be used to develop better educational interventions and policies. Therefore, a quantitative approach is an important and useful method to gain a deeper understanding of this topic (Dowker et al., 2016).

### Research Subjects in Publications Studied

Research on anxiety and SRL in journals involves a variety of subjects from different educational levels. The most researched subjects are university students, with 10 studies, as university students are at a more advanced stage of education where SRL skills are crucial for academic success and anxiety management is often a major challenge. Research such as that conducted by Gabriel et al. (2020) shows that math anxiety and SRL have a significant relationship with college students.

At the high school level, there are 8 studies involving students. This shows that anxiety and SRL are also important concerns during this transition period to higher education. According to Rozgonjuk et al. (2020), high school students experience math anxiety which can affect their approach to learning.

Junior high school students were recorded in 7 studies, which also indicates significant attention to the development of SRL and anxiety management skills at a younger age. Research by El-Adl and Alkharusi (2020) showed that test anxiety was negatively related to SRL ability among junior high school students in Oman. In contrast, primary school students were the least researched subjects, with only 3 studies. This may be due to the limited level of understanding and application of SRL at this age, as well as challenges in accurately measuring anxiety among younger children.

The types of research conducted in the studies on anxiety and SRL are varied, indicating a rich landscape of methodologies that can serve as a reference for future researchers. The predominance of quantitative research, alongside correlational, descriptive, survey, and other methods, provides a comprehensive foundation for understanding the complex relationships between anxiety and SRL.

This diversity in research approaches can be a valuable consideration for other researchers looking to expand their studies. By exploring different methodologies, they can uncover new insights and develop innovative interventions to address the challenges faced by students. The existing body of research not only reinforces the validity of these approaches but also encourages further investigation into less commonly used methodologies, such as experimental or mixed methods, to gain a deeper understanding of these critical educational issues.

### Research Instruments in Publications Studied

The research on anxiety and SRL in the journal involved a variety of subjects from different educational levels. The most researched subjects are university students, with 10 studies, possibly because university students are at a more advanced stage

of education where SRL skills are critical for academic success and anxiety management is often a major challenge. In addition, access to university students for research purposes also tends to be easier than other groups (Gonzalez-DeHass, 2020; Guo et al., 2015).

At the high school level, there were 8 studies involving students, suggesting that anxiety and SRL are also important concerns in this transition to higher education. Junior high school students were included in 7 studies, which also indicates significant attention to the development of SRL and anxiety management skills at a younger age (Kesici et al., 2009).

In contrast, primary school students were the least researched subjects, with only 3 studies. This may be due to the limited level of understanding and application of SRL at this age, as well as challenges in accurately measuring anxiety among younger children (Hurst & Cordes, 2017).

The diverse research instruments utilized in studies on anxiety and SRL contribute significantly to the field by providing a variety of tools that future researchers can consider. The range of instruments, including surveys, assessments, and observational tools, demonstrates the multifaceted nature of these topics and highlights different ways to measure and analyze the relationship between anxiety and SRL.

This variety of research instruments can serve as a valuable reference for other researchers looking to expand their studies. By employing different instruments or adapting existing ones, researchers can uncover new dimensions of understanding and develop innovative methodologies to address the challenges faced by students. Furthermore, the exploration of various instruments encourages further investigation into the effectiveness and applicability of different measurement tools in educational research.

### **Analysis Methods in Publications Studied**

In research on anxiety and SRL, various data analysis methods were used to analyze the results. The most widely used method was regression, with 9 studies. This method is popular due to its ability to identify and measure the relationship between different variables, as well as predict the impact of one variable on another, which is particularly relevant in the study of anxiety and SRL.

In addition, structural equation modeling (SEM) and descriptive analysis were each used in 6 studies. SEM is used to test complex theoretical models and relationships between latent variables, while descriptive analysis provides an overview of the data collected and assists in understanding the distribution and characteristics of the data (Villavicencio & Bernardo, 2016).

The correlation method was used in 3 studies, providing a simple way to evaluate the linear relationship between two variables. The t-test was used in 4 studies to compare the means of two groups, which is useful in identifying significant differences in anxiety levels or SRL between different groups. In contrast, the least used analysis methods were Chi-square, Pant analysis, ANOVA, and non-parametric statistics, each used in only 1 study. This may be due to limitations in their specific applications or the need for certain conditions for their use. Nonetheless, each method has its utility in the right context and makes an important contribution to research data analysis.

The various analysis methods employed in the publications on anxiety and SRL make a significant contribution to the field by offering a wide array of techniques that future researchers can consider. The use of methods such as regression, SEM, and descriptive analysis illustrates the complexity of the relationships being studied and provides insights into different ways to interpret and analyze data.

This diversity in analysis methods can serve as a valuable reference for other researchers looking to expand their studies. By exploring and applying different analytical techniques, researchers can uncover new findings and deepen their understanding of the factors influencing anxiety and SRL. Furthermore, the variety of methods encourages further exploration into the effectiveness of different analytical approaches, enabling the development of more nuanced and robust research designs in the educational context.

### **Objectives & Findings in Published Research Works**

Research on SRL and math anxiety has yielded important insights into how these two factors affect students' academic performance. Studies by Singh (2019), Cahyawati (2023), and Gabriel (2020) showed that better instructional strategies are needed to help students understand math concepts more deeply and manage their anxiety. Research by Balali (2023) and Andres (2023) revealed that cognitive understanding and support in the learning environment play an important role in reducing math anxiety and improving learning outcomes. Findings from Fajri and Amir (2022) and Atsnan (2023) suggest that self-directed learning and metacognitive support can help reduce math anxiety, which is important for creating a more positive learning experience. Siregar (2023) and Roick (2018) emphasized that innovative approaches and the use of metacognitive strategies can support independent learning as well as address mathematics anxiety. Research by Rayoan (2021) and Gursel (2023) found that the relationship between test scores, SRL strategies, and math anxiety can vary based on factors such as gender and grade level, suggesting the need for targeted interventions to support students experiencing high anxiety. Delima (2024) assessed that technology, such as ChatGPT, had a positive impact on self-directed learning, although music did not show significant differences in reducing math anxiety. Research by Priharvian (2024) and Vahidi (2018) highlighted how math anxiety and self-directed learning affect students' academic performance, with differences based on gender and learning conditions. Overall, this research emphasizes the importance of developing strategies that support self-directed learning and reduce mathematics anxiety to improve students' mathematics learning outcomes and create a more effective learning environment.

The objectives and findings of published research on SRL and math anxiety provide essential insights that can significantly contribute to the field. The diverse goals of these studies, ranging from understanding the relationship between anxiety and SRL to exploring effective interventions, offer a comprehensive framework for future research.

These findings not only enhance our understanding of the factors affecting students' academic performance but also highlight the need for targeted strategies to support learners. By identifying key areas where anxiety and SRL intersect, future researchers can focus their efforts on developing innovative approaches and interventions.

The insights gained from these studies can serve as a valuable reference for other researchers looking to expand their work in this area. By building on these objectives and findings, they can contribute to a deeper understanding of the challenges faced by students and help create more effective educational environments. Furthermore, the identification of gaps in the current research can guide future investigations, ensuring that emerging issues are addressed and explored in greater depth.

## CONCLUSION

Based on the findings and analyses presented, the following conclusions are drawn:

1. There is a relationship between SRL and mathematics anxiety in the context of mathematics learning. Through a systematic literature review, consistent findings indicate a relationship between students' SRL levels and their levels of mathematics anxiety.
2. High mathematics SRL is associated with low mathematics anxiety. Previous researchers found that students with high self-confidence in their mathematical abilities tend to experience lower anxiety when learning mathematics.
3. The results of this literature review can provide insights and recommendations for educational practitioners and researchers in improving mathematics learning. With a better understanding of the relationship between SRL and mathematics anxiety, learning strategies can be developed.

This article provides a comprehensive overview of the relationship between SRL and mathematics anxiety in the context of learning. With a better understanding of this relationship, more effective learning strategies can be implemented to improve students' achievement and comfort in learning mathematics.

The primary findings indicate that fostering SRL can significantly alleviate mathematics anxiety among students, highlighting the importance of teaching strategies that promote self-efficacy and motivation. Theoretically, this suggests a need to integrate SRL frameworks into educational psychology research to better understand their interplay with anxiety. Practically, educational institutions should prioritize interventions that enhance SRL to improve student outcomes in mathematics.

### Limitations of This Study

This research is limited by the limited availability of empirical data from some of the studies used, variations in methodology and research design in the articles, as well as differences in cultural and educational contexts that may affect the results and generalizability of the findings. In addition, some studies may have small or underrepresentative sample sizes, as well as publication bias that may affect the conclusions drawn from the reviewed literature.

### Suggestion

The suggestions given based on the limitations of the research in this journal are, as follows:

1. **Further empirical research:** Additional empirical research with a larger and more representative sample size is needed to deepen the understanding of how self-directed learning affects students' math anxiety.
2. **Methodological consistency:** Future research should utilize consistent methodologies and research designs to allow for more accurate and valid comparisons between different studies.
3. **Cultural context considerations:** It is important to consider different cultural contexts and educational systems to make research results more relevant and generalizable to various student populations.
4. **Overcoming publication bias:** Efforts should be made to overcome publication bias by publishing both positive and negative findings, thus providing a more objective picture of the effects of self-directed learning on math anxiety.
5. **Use of mixed research methods:** It is recommended to use mixed research methods (quantitative and qualitative) to gain deeper insights into the mechanisms and factors that influence the relationship between self-directed learning and math anxiety.

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**Declaration of interest:** No conflict of interest is declared by the authors.

**Data sharing statement:** Data supporting the findings and conclusions are available upon request from the corresponding author.



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## APPENDIX A

Table A1. Studies

No	Reference	Title	Type of research (A)	Research subjects (B)	Instruments (C)	Analysis method (D)
1	Singh et al. (2019)	The relationship between self-regulated learning and mathematics attitude towards college students development of mathematical thinking	Correlational research	University students	Questionnaires and tests	Correlation
2	Balali et al. (2023)	The intermediating role of self-regulation in the relationship between math educational beliefs and students' math anxiety	Correlational research	Senior high school	Questionnaire	SEM
3	Rayoan and Ludji (2021)	The influence of mathematics national examination scores on grade point average, mathematics anxiety, and self-regulated learning of 2018 second-year students	Quantitative research	University students	Questionnaire	Regression and MANOVA
4	Cahyawati et al. (2023)	The impact of undergraduate student's mathematics anxiety and self-concept on their self-regulated learning and academic achievement	Descriptive research	University students	Questionnaire	SEM
5	Gabriel et al. (2020)	The impact of mathematics anxiety on self-regulated learning and mathematical literacy	Quantitative research	Senior high school	Questionnaire	SEM
6	Matricion (2021)	Mathematical anxiety as predictor of learning motivation strategies	Predictive research	Senior high school	Questionnaire	Regression
7	Fajri and Amir (2022)	Math self-regulated learning assisted by metacognitive support by reviewing sex differences in mathematics anxiety	Quantitative research	Elementary school	Metacognitive	Regression
8	Gürsel et al. (2023)	High school students' level of mathematics anxiety and use of self-regulatory learning strategies	Correlational research	Senior high school	Rating scale	t-test and MANOVA
9	Thamrin et al. (2019)	Self-efficacy, academic anxiety, and self-regulated learning on mathematics achievement at vocational high school	Survey research	Senior high school	Questionnaire	SEM
10	Andres et al. (2023)	Anxiety, achievement, and self-regulated learning in CueThink	Quantitative research	Elementary school and junior high school	Rating scale	Descriptive analysis
11	Delima et al. (2024)	The students' mathematics self-regulated learning and mathematics anxiety based on the use of ChatGPT, music, study program, and academic achievement	Correlational research	University students	Questionnaire	Non-parametric statistics
12	Priharvian et al. (2024)	Multiple regression analysis: Effects of math anxiety and self-regulated learning on learning outcomes	Quantitative research	Senior high school	Rating scale	Regression and Chi-square
13	Siregar et al. (2023)	Increasing students self-regulated learning through a realistic mathematical education	Descriptive research	Junior high school	Questionnaire	Descriptive analysis
14	Rican et al. (2022)	Aspects of self-regulated learning and their influence on the mathematics achievement of fifth graders in the context of four different proclaimed curricula	Survey research	Elementary school	Observation	Descriptive analysis
15	Roick and Ringeisen (2018)	Students' math performance in higher education: Examining the role of self-regulated learning and self-efficacy	Survey research	University students	Metacognitive	SEM
16	Atsnan et al. (2023)	Math anxiety, self-regulated learning, and academic procrastination in class VIII students: A case study at SMPN 2 Alalak	Correlational research	Junior high school	Questionnaire	Correlation
17	Duru and Okeke (2021)	Self-regulated learning skill as a predictor of mathematics achievement: A focus on ability level	Predictive research	Junior high school	Questionnaire	Regression
18	Tashtoush et al. (2022)	The effectiveness of self-regulated learning (SLR) in creative thinking for calculus students	Quantitative research	Junior high school	Test	t-test or ANOVA
19	Erita et al. (2022)	The flipped classroom effect on students' self-regulated learning	Quasi-experimental	Junior high school	Questionnaire	t-test
20	Delima and Cahyawati (2021)	Students' mathematics self-concept, mathematics anxiety, and mathematics self-regulated learning during the COVID-19 pandemic	Quantitative research	University students	Observation	Descriptive statistical analysis, correlation analysis, and regression analysis

**Table A1 (Continued).** Studies

No	Reference	Title	Type of research (A)	Research subjects (B)	Instruments (C)	Analysis method (D)
21	Tashtoush et al. (2020)	The effect of using self-regulated learning strategy to reduce the level of mathematics anxiety among students of al-huson university college	Experimental research	University students	Questionnaire	t-test or ANOVA
22	Musso et al. (2019)	Individual differences in basic cognitive processes and self-regulated learning: Their interaction effects on math performance	Quantitative research	University students	Questionnaire and test	Regression
23	Vahidi et al. (2018)	The role of executive functions and self-regulation learning levels in predicting math anxiety	Mixed research	Elementary school	Questionnaire	SEM
24	Herawati et al. (2020)	Self-efficacy, social support, academic flow, and math anxiety among Islamic senior high school students	Quantitative research	Senior high school	Rating scale	Regression
25	Wang (2023)	Self-concept, learning anxiety, and performance in mathematics learning: The moderating effect of teacher cognitive activation	Quantitative research	Junior high school	Test	Regression
26	Ghahremani et al. (2022)	Presenting a model of relationships between classroom perception, self-regulation, students and math anxiety in high school students	Descriptive and correlational research	University students	Questionnaire	Path analysis
27	Dirgantoro and Soesanto (2021)	Analysis of self-regulated learning of students in mathematics education study program in number theory course	Descriptive research	University students	Rating scale, questionnaire, and interview	Descriptive analysis
28	Hutt et al. (2021)	Who's stopping you?—Using microanalysis to explore the impact of science anxiety on self-regulated learning operations	Descriptive research	Senior high school	Observation, test, and questionnaire	Descriptive analysis

## APPENDIX B

Table B1. Research objectives and findings of the studies

No	Reference	Research objectives	Findings
1	Singh et al. (2019)	Explore the relationship between SRL, students' attitudes toward mathematics, and the development of their mathematical thinking.	This research underscores the complexity of mathematics learning among college students and points to the need for better instructional strategies that promote deeper understanding and application of mathematical concepts.
2	Balali et al. (2023)	Exploring the mediating role of self-regulation in the relationship between math education beliefs and students' math anxiety.	This research highlights the importance of understanding the cognitive elements associated with math education and their impact on students' emotional responses, particularly anxiety. By addressing these factors, educational institutions can create a more supportive environment that promotes better learning outcomes and reduces math-related anxiety.
3	Rayoan and Ludji (2021)	This study sought to determine whether there is a significant correlation between the scores obtained in the national mathematics exam and students' GPA, level of mathematics anxiety, and their ability to self-regulate their learning process.	The study concluded that while national math test scores are often considered critical, they did not significantly affect GPA, math anxiety, or self-directed learning among the students studied.
4	Cahyawati et al. (2023)	This study sought to determine whether there is a significant correlation between the scores obtained in the national mathematics exam and students' GPA, level of mathematics anxiety, and their ability to self-regulate their learning process.	This research highlights the complex interactions between math anxiety, self-concept, self-directed learning, and academic achievement, providing insights that can inform educational strategies to support students with math-related challenges.
5	Gabriel et al. (2020)	Explores the complex relationships between mathematics anxiety (ma), self-directed learning (srl), and mathematics literacy among students, focusing primarily on the Australia subset of the 2012 program for international student assessment (PISA).	This research contributes to a deeper understanding of the dynamics between math anxiety, self-directed learning, and academic performance in mathematics, providing valuable insights for educators and policymakers.
6	Matricion (2021)	To investigate how math anxiety predicts the utilization of motivational learning strategies among high school students enrolled in science, technology, engineering, and mathematics programs.	Research provides insight into how anxiety affects students' adoption of motivational learning strategies, emphasizing the need for educators to create a supportive learning environment conducive to regulating effort, peer interaction, and access to resources.
7	Fajri and Amir (2022)	This study aimed to investigate the impact of math self-learning and metacognitive support on math anxiety among third-grade elementary school students in Sidoarjo, Indonesia. The study explored how math self-learning and metacognitive support can help reduce math anxiety and understood the relationship between these variables and their effect on the affective aspects of math anxiety.	This study shows that students' learning independence and metacognition contribute positively to the reduction of math anxiety, especially on the affective dimension of anxiety. These findings emphasize the importance of metacognitive strategies in enhancing students' learning experience and reducing mathematics anxiety.
8	Gürsel et al. (2023)	This study aims to examine the level of math anxiety and the use of self-directed learning strategies among 11th and 12th-grade students in secondary schools, as well as understand the relationship between these two variables based on factors such as gender and grade level. This study also fills a gap in the literature in Turkey regarding the relationship between math anxiety and self-directed learning strategies in a secondary school setting.	<ul style="list-style-type: none"> <li>- Gender differences: Female students showed higher math anxiety and used more independent learning strategies than male students.</li> <li>- Grade level differences: Grade 11 students had higher math anxiety than grade 12 students.</li> <li>- Math achievement: There was a significant difference in math anxiety levels based on math achievement scores, but no significant difference in the use of self-directed learning strategies.</li> <li>- Correlation: No correlation was found between math anxiety and the use of self-directed learning strategies.</li> </ul> These findings suggest the importance of targeted interventions to support students, especially female students and those in lower grades.
9	Thamrin et al. (2019)	To investigate the effects of self-efficacy, academic anxiety, and self-directed learning on math achievement among high school students in Bogor, West Java, Indonesia.	This research highlights the important role of self-efficacy and self-directed learning in improving mathematics achievement while emphasizing the detrimental effects of academic anxiety on learning outcomes and self-regulation.
10	Andres et al. (2023)	Explore the relationship between anxiety, self-directed learning (SRL), and achievement in the context of an interactive learning environment (ILE) called cuethink.	This research highlights the important role of anxiety in educational settings, especially in interactive learning environments, and underscores the need for targeted interventions to support anxious students in their learning journey.
11	Delima et al. (2024)	This study investigated the impact of ChatGPT technology and music on students' math self-learning and math anxiety during independent study sessions. In addition, the study explored the relationship between mathematics self-directed learning and mathematics anxiety with students' chosen program of study as well as their academic achievement, filling a gap in mathematics education research related to technology and music.	The research found that ChatGPT had a positive impact on math self-learning, while music made no significant difference. There was no significant difference in math anxiety related to the use of ChatGPT or music. A significant relationship was found between mathematics self-directed learning and students' course of study, but there was no significant relationship between mathematics anxiety and course of study, or between mathematics self-directed learning and academic achievement. These findings provide valuable insights into the role of technology and music in mathematics education.

**Table B1 (Continued).** Research objectives and findings of the studies

No	Reference	Research objectives	Findings
12	Priharvian et al. (2024)	This study investigates the effects of math anxiety and self-directed learning on the academic performance of secondary school students in Yogyakarta, Indonesia. The aim is to understand how emotional and cognitive factors influence learning outcomes and to help educators develop strategies that improve students' learning experiences and outcomes.	<ul style="list-style-type: none"> <li>- Female students: math anxiety and self-directed learning accounted for 86.7% of the variance in academic performance.</li> <li>- Male students: the combined effects of math anxiety and self-directed learning accounted for 15.8% of the variance in academic performance.</li> <li>- Regression model:               <ul style="list-style-type: none"> <li>o Female students: performance = <math>-9.077 + 0.455 (\text{anxiety}) + 0.826 (\text{self-directed learning})</math></li> <li>o Male students: performance = <math>0.815 (\text{anxiety}) + 0.480 (\text{self-directed learning})</math></li> </ul> </li> </ul> <p>These findings emphasize the importance of addressing emotional and cognitive factors in education to improve student learning outcomes.</p>
13	Siregar et al. (2023)	This study was to determine the improvement of independent learning among students through a realistic mathematics education approach.	The research showed that 95.68% of students responded positively to the realistic mathematics education approach, enhancing their independent learning. Realistic mathematics education effectively promotes independent learning, emphasizing the importance of innovative teaching methods. The use of various learning models helps students organize their learning. Future research is suggested to further explore, complementing other mathematical skills through this approach.
14	Rican et al. (2022)	This study aims to explore aspects of self-directed learning and their influence on fifth-grade students' mathematics achievement across four different curricula.	This study provides valuable insights into how aspects of self-directed learning contribute to mathematics achievement among fifth-grade students, emphasizing the role of teaching methods and students' self-perceptions in their academic success.
15	Roick and Ringeisen (2018)	This study aims to investigate the role of learning strategies and self-efficacy in students' mathematics performance, as well as explore the relationship between cognitive and metacognitive strategies and self-efficacy, and their impact on mathematics performance over two semesters.	These findings suggest that self-efficacy influences learning strategy use and academic performance, with a complex relationship between metacognitive strategies and exam outcomes, and highlight the need for longitudinal research to understand the causal role of self-efficacy in mathematics learning in higher education.
16	Atsnan et al. (2023)	This study aims to determine the level of math anxiety, assess self-directed learning, evaluate academic procrastination among students, and investigate the relationship between math anxiety and academic procrastination, and self-directed learning and academic procrastination.	The study found that 62.90% of students had a medium level of math anxiety, 54.84% had a medium level of independent learning, and 75.81% had a medium level of academic procrastination. There was a positive relationship between math anxiety and academic procrastination and a negative relationship between self-directed learning and academic procrastination.
17	Duru and Okeke (2021)	To investigate the role of self-directed learning skills as predictors of math achievement among secondary school students, focusing on different ability levels.	This research underscores the important role of self-directed learning skills in predicting math achievement, especially across different ability levels, and calls for educational interventions to foster these skills among students.
18	Tashtoush et al. (2022)	Improve educational practices in mathematics by enhancing students' creative thinking skills through self-directed learning, identifying effective teaching strategies, and addressing learning challenges faced by students.	This research provides valuable insights into how literature learning strategies can improve students' creative thinking skills in calculus subjects.
19	Erita et al. (2022)	To improve learning outcomes, promote self-directed learning, adapt to challenges, evaluate teaching methods, inform practice, and encourage active student participation.	The findings of this study highlight the importance of the flipped classroom model in enhancing students' independent learning, as well as providing valuable insights for students in designing more effective learning strategies.
20	Delima and Cahyawati (2021)	To assess how students' perceptions of their mathematical ability (MSC), their feelings of anxiety related to mathematics (ma), and their ability to self-regulate their learning (msrl) were affected during the pandemic.	This research highlights the importance of math self-concept in encouraging self-directed learning among students, especially during challenging times such as the COVID-19 pandemic, while also revealing the pervasive problem of math anxiety among students.
21	Tashtoush et al. (2020)	This study aims to investigate the effectiveness of using self-directed learning strategies to reduce math anxiety among students at al-Huson University College in Yordani.	The findings emphasize the positive impact of self-directed learning in reducing mathematics anxiety and suggest its integration into teaching practices to support students in overcoming academic hurdles and fostering positive attitudes toward learning mathematics.
22	Musso et al. (2019)	This study aims to explore the relationship between cognitive and motivational factors and their impact on mathematics performance among university students, focusing on working memory capacity (wmc), executive attention, and self-directed learning (srl).	Research emphasizes the importance of cognitive and motivational factors in academic performance, suggesting that effective enhancement of WMC and SRL strategies can improve students' mathematics outcomes. This analysis provides insight into the optimization of cognitive resources and self-regulation strategies to support better academic performance in mathematics.

**Table B1 (Continued).** Research objectives and findings of the studies

No	Reference	Research objectives	Findings
23	Vahidi et al. (2018)	This study investigated the role of executive functioning and self-directed learning in predicting math anxiety in students with math learning disabilities. The focus was on determining the contribution of executive functioning and the level of self-directed learning to math anxiety in these students.	Executive function and self-directed learning play an important role in reducing math anxiety in students with learning disabilities. Improvement through advanced training courses can help reduce math anxiety.
24	Herawati et al. (2020)	This study aims to explore the relationships among mathematics self-efficacy, social support, academic flow, and mathematics anxiety among Islamic high school students.	This study highlights the importance of social support and academic flow in reducing math anxiety, providing valuable insights for educators and stakeholders in addressing this common problem among students.
25	Wang (2023)	This study explores the relationship between students' self-concept in mathematics, learning anxiety, and mathematics performance, as well as the moderating effect of teacher cognitive activation.	This research provides valuable insights into how self-concept, learning, and teacher support interact to influence students' performance in mathematics.
26	Ghahremani et al. (2022)	Structural equation modeling was used to test the conceptual model. It seeks to examine the relationship between classroom perception, self-regulation, educational knowledge, and math anxiety. This study aims to understand how these factors interact and influence each other in the context of high school students in Tehran.	These findings highlight the importance of classroom environment and educational knowledge in promoting self-regulation and reducing anxiety among high school students.
27	Dirgantoro and Soesanto (2021)	Analyzes the independent learning of students enrolled in a number theory course in a mathematics education study program. Specifically, it investigates how students adapt their learning strategies and independence in the absence of response classes, which are typically supportive learning environments that help students engage with the material more effectively.	These findings highlight the importance of self-directed learning in academic success, especially in challenging subjects such as number theory, and suggest that fostering self-confidence and reducing anxiety can improve students' learning experience.
28	Hutt et al. (2021)	Investigating how science anxiety affects students' self-directed learning (SRL) strategies, especially in computer-based learning environments	This research provides valuable insights into the impact of science anxiety on independent learning, emphasizing the need for targeted support for anxious students in educational settings.