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Unraveling the connection: A systematic review of learning styles and mathematics achievement

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ABSTRACT

Mathematics is an essential subject in schools, helping develop cognitive skills such as critical analysis, logical reasoning, and problem-solving. However, academic achievement in mathematics often declines, with some students having difficulty understanding mathematical ideas. Many factors influence mathematics achievement, including students' learning styles. This study aims to identify students' learning styles and how they may affect their academic performance. The study's findings indicate that mathematics often uses visual-spatial learning mode. Understanding mathematical concepts usually requires first seeing shapes and relationships. Schools are advised to train instructors in learning style-based teaching methods because a better understanding of students' learning styles can improve engagement and academic achievement.

Keywords: learning styles, mathematics achievement, problem-solving

INTRODUCTION

Mathematics is an essential subject in education (Adusei & Owusu Sarfo, 2020), which plays a role in the progress of cognitive ability (Jamil & Ghazali, 2018; Susilo et al., 2023) for example, problem-solving (Prapti et al., 2023; Serbin & Wawro, 2024), logical thinking (Bonyah et al., 2023; Ontuganova et al., 2023) and critical analysis (Kania et al., 2023; Yu et al., 2024). Ideally, solving mathematical problems or problems relevant to mathematics requires conceptual understanding (Kania & Juandi, 2023; Nita et al., 2023). An ideal mathematics curriculum needs to expand a well-defined set of abilities in important mathematical content regions (e.g., integer, fractions, component of geometry, and mensuration) in the early ranks to prevent difficulties in later grades (Kiernan & Borman, 2013; Lannin et al., 2015). In addition, ideal mathematics teaching behaviours can include discussing significant content relating to mathematics instruction, emphasising active learning, and supplying comprehensive records for the instructor (Álvarez et al., 2022; Hamidah et al., 2024).

School grades, including mathematics achievement, can predict students' academic success (Gambini et al., 2024). However, mathematics achievement often declines, with some students having difficulty understanding mathematical concepts and showing a lack of stimulus and self-confidence (Maskar & Herman, 2023). In Indonesia, student achievement in mathematics is relatively low (Efendi & Suastra, 2023; Wawan & Retnawati, 2022). Joshi (2024) also said that mathematics achievement in Hong Kong has declined in recent years. In 2011 and 2012, two rural school districts in the southeastern United States reported low mathematics achievement among students and an apparent decline in mathematics achievement (Angraini et al., 2023; Salters, 2019). The low accomplishment of students in mathematics learning is demonstrated by the 2018 PISA report, which was captured from an assessment of 600,000 15-year-old students in 79 nations with high and middle-income PISA attendees by comparison the reading, mathematics, and science show of each learner in all countries that were the object of PISA (Sinaga, 2022).

This decline in achievement is influenced by various factors, comprising direct and indirect effects, for example, students' perceptions of teacher capability, learning anxiety, problem-solving skills, learning stimulus, and mathematical relationship skills (Febrianti & Dasari, 2024; Wawan & Retnawati, 2022). One crucial factor influencing mathematics achievement is the student's learning style. Learning styles are potent indicators of students' personal preferences for treatment and learning information and their communication with learning materials, environs, and other students (Feldman et al., 2015; Topu, 2024). Because learning styles can assist students and coaches become more aware of their powers and weaknesses, they are very relevant in education (Feldman et al., 2015; Nurhayati & Nurandini, 2023). Romanelli et al. (2009) also revealed that many people believe that learning style is an aspect of the success of higher education. Students' learning styles differ from one another, both between the disciplines they study and between individuals (Türker & Bostancı, 2023).

Several studies have investigated the connection between learning styles and academic performance in various subjects. Every student must understand their learning style. Knowing students' learning styles also helps them learn more effectively and build self-confidence (Srivastava & Shah, 2022). It is essential to consider how learning styles affect one's critical thinking capacity because failure to recognise one's learning style can result in a lack of competence. Since learning styles can be an important factor in students' mathematics achievement, a study will be conducted using the systematic literature review method to reveal what learning styles students use that affect students' mathematics achievement.

LITERATURE REVIEW

Mathematics remains recognised as the essential basis of other disciplines; nevertheless, many students still perceive it as tricky and abandon it (Diego-Mantecon et al., 2021). Mathematical problem-solving is challenging in building students' conceptual understanding (Walsh & Gervasoni, 2023). All learners are unusual and have various learning needs. Variety also comprises students with various learning styles (Javed et al., 2023). This literature review aims to analyse the correlation between learning styles and mathematical achievement and explore the learning styles employed to enhance learning results.

According to Howard Gardner, humans possess a minimum of seven potential intelligences. The seven intelligences encompass visual-spatial, linguistic, musical, kinaesthetic, logical-mathematical, interpersonal, and intrapersonal intelligence (Gardner, 1993). The primary cognitive abilities in mathematics encompass visual-spatial intelligence and logical-mathematical intelligence. Visual instruction is critical to increase students' spatial intelligence comprehension speed in numerous mathematical disciplines. Individuals with logical-mathematical intelligence typically employ problem-solving techniques and mathematical analysis in their learning, as mathematics necessitates logical and analytical thinking abilities.

Given the variation in learning styles among students, some experts suggest that mathematics teachers embrace the idea of differentiated learning (Mangwende & Maharaj, 2019). Cognitive, affective, and intellectual factors influence learning styles, the way individuals communicate and react to the learning environment (Duff & Duffy, 2002). Learning styles refer to an individual's cognitive processes and understanding of information (Arono et al., 2022). Students' learning styles encompass a variety of modalities, such as visual, linguistic, kinesthetic, and others (Tambunan et al., 2019). Visual learners acquire knowledge primarily through visual stimuli, linguistic learners primarily through auditory stimuli, and kinesthetic learners primarily through physical movement and tactile sensations (Nguyen et al., 2024). According to learning style theories, individuals have distinct learning preferences and are likelier to achieve optimal learning outcomes when using their preferred learning methods (Ma, 2024).

METHODOLOGY

We conducted an extensive systematic literature review to address our research issue. The simple linear regression approach is suitable for collecting data on specific subjects if they meet certain qualification criteria (Kania & Kusumah, 2023; Mengist et al., 2020). This research does not provide a publication year limit to understand various periods comprehensively. We used Preferred Reporting things for Systematic Reviews and Meta-Analysis (PRISMA) to examine the combined journal articles. Conde et al. (2020) defined PRISMA as a standardised, peer-reviewed methodology that utilises checklist guidelines to ensure quality and duplicability in the research revision procedure. The PRISMA process consists of four phases: eligibility, inclusion, screening, and identification. The initial stage involves identification. The following paragraphs provide a comprehensive analysis of these stages. We chose this strategy because it allows us to incorporate interesting scientific publications. Following PRISMA principles, we can accurately determine the best method for integrating learning styles into mathematics.

Systematic Review Process

Identification

We used Scopus and Eric to perform the search. Based on our preliminary study, we formulated two main search terms: learning styles and mathematics (**Table 1**). We have compiled synonyms and alternative phrases from the most frequently searched terms. Therefore, we expanded our criteria and approach to investigate more relevant studies. We use the main search keywords generated by combining the found words to perform the search. We use the "OR" operator to separate each synonym and the "AND" operator to connect the second keyword. We used search techniques with Scopus and Eric to get 4230 results. We also identified 15 duplicate journal articles. At this stage of the process, we classified 4215 journal articles.

Table 1. Lexical equivalents and replacement expressions for the main search keywords are available

Learning style	Math
Cognitive style	Mathematical
Education method	Mathematics
Why you learn	Arithmetical
Leather jacket	Numerical
Pedagogical strategy	Rigorous
Study technique	Scientific
Knowledge acquisition method	Statistical
Cognitive process	Geometric
	Algebraic

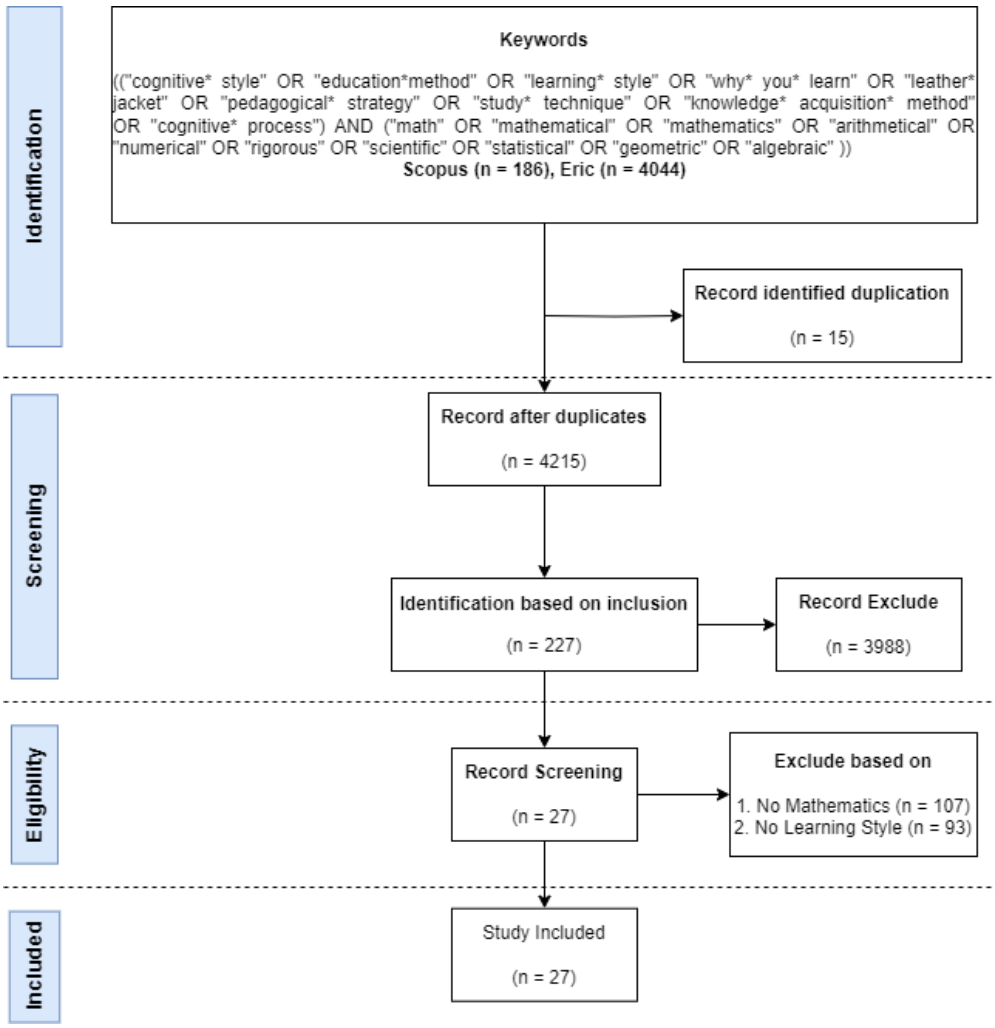

Figure 1. PRISMA flow diagram (Source: Authors' own elaboration)

Screening

Figure 1 shows that the selection process complies with PRISMA criteria, as Moher et al. (2009) outlined. This method uses various criteria to include and exclude certain elements. We excluded systematic review volumes, book chapters, and conference proceedings from the literature collection. Our focus is only on English-language journal papers due to the prevalence of such publications, thereby reducing the need for uncertain or unclear translations. Additionally, we did not restrict the publication years of the articles to gain a broad understanding of the research findings in different periods. We exclusively include open-access publications to simplify the study process. There are no exceptions or exceptions for specific countries or regions. After the screening stage, study criteria rendered 3988 publications ineligible. Furthermore, only 227 articles are still available.

Eligibility

Figure 1 shows that the feasibility stage arises from an incomplete article. We initially excluded journal papers that did not discuss learning styles or mathematics. We then comprehensively assessed every article's title, abstract, methodology, findings, and discussion to ensure that the 227 publications met the study's criteria and objectives. We have rejected 200 papers due to insufficient explanation of mathematics learning styles or unclear presentation and evaluation of research data in the research finding part. As an outcome, in the final phase of the review process, 27 papers were selected for publication (see **Figure 1**).

Inclusion and exclusion criteria

After collecting data with all specified origins, we used option criteria, including document type, language, and topic area, to eliminate publications unrelated to our research. Explaining the inclusion and exclusion criteria is essential when choosing which studies to include and exclude. This ensures that the selected studies are directly related to the main objectives of the main study. **Table 2** presents the specific criteria that determined whether or not a paper was included in this evaluation, along with related research findings. We considered 27 relevant papers and obtained the full texts of these publications.

Table 2. Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Document Type	Article	Proceeding, book, chapter, etc.
Publication Type	Final	In process, review, etc.
Source type	Journal	Book, chapter, proceeding, etc
Language	English	Non-English
Open access	Open access	Close access

RESULTS

Using Learning Styles in Mathematics

All identified publications studied the use of learning styles in mathematics. All listed studies focused on using learning styles as a direct or indirect goal. The select studies covered all levels of education in diverse geographical locations worldwide. **Table 3** illustrates the scope of learning styles in mathematics and the focus points.

Table 3. Use of learning style in mathematics

Study	Participants	Types of learning styles	MA	Results	GLC
English (2023)	Students in the 12th-grade educational environment	Kinesthetic	Class-based research	Multiple cognitive approaches are essential for proficient problem-solving in STEM fields.	United States of America
Kennedy (2009)	Students from primary to secondary education levels	Logical-mathematical	Qualitative approach based on observation and dialogue analysis	Applying dialogic pedagogy in communities of mathematical inquiry (CMI) can potentially improve students' understanding of mathematics.	Bulgaria
Fugard and Stenning (2013)	Individuals engaged in several cognitive activities to gather data on cognitive disparities.	Logical-mathematical	Utilising statistical models to understand variations in thinking across individuals.	Statistical models can be utilised as efficient cognitive models to comprehend variations in thinking across individuals.	England
Carpenter et al. (2022)	Students registered in the PharmD program at Texas Regional University Timus	Interpersonal	Health sciences thinking test-numeracy (HSRT-N)	The TBL approach dramatically enhances the arithmetic abilities of pharmacy students.	Texas
Arifin et al. (2020)	Students in three schools. There are SMAN 1 Wringinanom Gresik, SMAN 1 Driyorejo Gresik and SMAN 1 Kedamean Gresik	Logical-mathematical	Experimental design with a quasi-experimental approach	Adapting the implementation of problem-based learning (PBL) to match students' cognitive styles has a useful effect on the growth of critical thinking abilities and the memory of course information.	Indonesia
Phuseengoen and Singhchainara (2022)	Junior high school students from two groups at the eighth-grade level at Satri Si Suriyothai School.	Kinesthetic	The research methodology integrates control and treatment groups to experiment.	Integrating STEM has a substantial positive influence on students' physical movement abilities and cognitive analytical thinking abilities.	Thailand
Liang et al. (2014)	Undergraduate and postgraduate students	Logical-mathematical	This study combines computer models to simulate and evaluate problem-solving procedures using fMRI.	These findings replicate recent functional magnetic resonance imaging (fMRI) investigations on tasks involving number series completion.	China
Lubna et al. (2023)	Students enrolled in a STEM education program at one of the faculties in Eastern Indonesia.	Kinesthetic	Evaluative research using an experimental approach	The critical thinking capability of STEM students who demonstrate field-dependent (FD) and field-independent (FI) cognitive styles shows a noticeable enhancement, hence meeting the necessary criteria for increasing critical thinking.	Indonesia
Lovemore et al. (2021)	A grade five student at a private school in the Eastern Cape.	Musical	Qualitative data collection	Integrating mathematics and music enhances students' understanding and fosters positive attitudes towards learning mathematics.	South Africa
Dinov et al. (2008)	Students taking probability courses	Visual-spatial and interpersonal	Qualitative and quantitative approaches through surveys	Using online statistical computing resources helps improve students' understanding of statistical principles.	United States of America

Note: MA: Methodological approach & GLC: Geographical location context

Table 3 (Continued). Use of learning style in mathematics

Study	Participants	Types of learning styles	MA	Results	GLC
Putri et al. (2024)	Auditory teacher	Visual-spatial, musical and kinestetic	Qualitative design that includes case studies.	Comprehending learning styles holds significant importance for both educators and learners.	Indonesia
Evendi et al. (2022)	Students taking common mathematics courses at the Faculty of Science and Engineering, Mandalika University of Education, Indonesia	Visual-spatial	Evaluative research with an experimental approach	Students' critical thinking skills are influenced by their cognitive style.	Indonesia
Siler (2015)	Artwork and graphics crafted by the author himself.	Visual-spatial	Qualitative and visual approaches	Visual depictions help to improve comprehension of the brain and nervous system's functions.	United States of America
Idrizi et al. (2023)	Undergrad students enrolled in two STEM e-learning courses in the Faculty of Computer Science and Engineering	Kinesthetic	Questionnaire	Gender has an impact on academic performance and learning method selection.	North Macedonia
Capinding (2021)	Middle and high school students, math teachers, parents/guardians	Visual-spatial	Descriptive correlational design	Learning styles can impact student academic performance, instructor instructional approaches, and parental strategies for educating their children.	Philippines
Özgen & Bindak (2012)	High school student	Visual-spatial and kinestetic	Descriptive research with survey model	Variances in learning styles can impact students' perspectives on using computers in mathematics instruction.	Turkiye
Parrot and Kwan Eu (2013)	Three students in grade five (Grade 11)	Visual-spatial and Kinestetic	Qualitative techniques such as interviews and observation for data collection.	TI-Nspire strengthens students' understanding of calculus concepts and stimulates mathematical thinking.	Malaysia
Kospentaris et al. (2016)	Math teacher and grade 11 students	Visual-spatial	Visual/analytical strategy test (VAST)	The VAST Analytical Strategy scale shows a strong positive correlation with students' performance in visuospatial and abstract thinking ability assessments.	Greece
Stubbs & Myers (2015)	Students, teachers and curriculum	Kinesthetic	Use a descriptive approach and incorporate an integrated multiple-case design	Integrating STEM into agriculture education can improve and increase students' learning experiences.	United States of America
Weckbacher & Okamoto (2018)	High school students	Visual-spatial	Using three cognitive ability tests	The findings indicate a substantial correlation between two spatial measures and geometric performance.	Japan
Altun (2018)	High school students	Logical-mathematical	Both quantitative and qualitative research approaches	Taking learning styles into account in educational environments can enhance academic performance.	Turkiye
Mhlolo (2013)	Math teachers and students in schools	Musical	Qualitative research approach	Implementing diverse instructional approaches in mathematics may be a potent tactic for improving the quality of teaching and boosting students' learning achievements.	South Africa
Altun & Serin (2019)	11 talented ninth-grade students from Bornova Anatolia high school	Logical-mathematical	Survey model	Those with an assimilator learning style tend to get greater scores in mathematics courses than those with other learning styles.	Turkiye
Gunčaga & Žilková (2019)	Elementary and middle school students	Visual-spatial	Experimental approach	Visualising techniques in mathematics instruction can improve primary school students' comprehension of geometric principles.	Slovakia
Cardino & Ortega-Dela Cruz (2020)	Class students and math teachers	Interpersonal, intrapersonal, and linguistic	Descriptive correlation	The outcome of the multiple retrogression analysis indicated that out of all the learning styles examined, only the intrapersonal style had a statistically significant impact on the academic success of 9th-grade pupils.	Philippines

Note: MA: Methodological approach & GLC: Geographical location context

Table 3 (Continued). Use of learning style in mathematics

Study	Participants	Types of learning styles	MA	Results	GLC
Maningo et al. (2021)	High school students	Kinesthetic	Quasi-experimental design	Geometric manipulative tools have the potential to enhance students' comprehension of geometric and mathematical principles in general.	Philippines
Purwasih et al. (2024)	High school student	Logical-mathematical	Qualitative approach	Integrating the mathematical semiotic method with computational thinking helps enhance students' comprehension of solving number pattern issues.	Indonesia

Note: MA: Methodological approach & GLC: Geographical location context

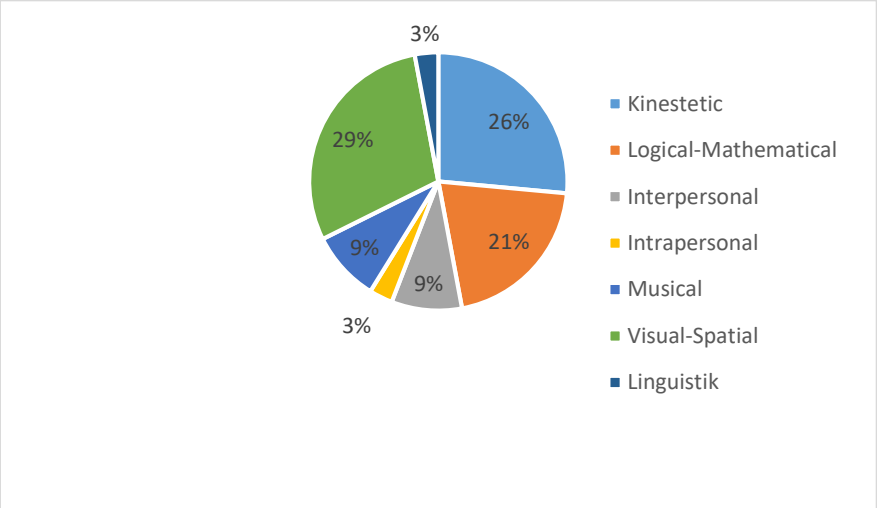

Figure 2. Distribution of learning style usage (Source: Authors' own elaboration)

Learning style studies (n = 27) were analysed and published over various years. This chart (**Figure 2**) addresses the following research question.

Learning Styles Used in Mathematics Education for the Sample Studied

The first investigate question is related to the learning styles used in mathematics education for the studied sample. The learning styles used in mathematics education for the studied sample are Visual-Spatial, Kinesthetic, Logical-Mathematical, Linguistic, Interpersonal, Intrapersonal, and Musical. As look in **Figure 2**, the bulk of learning styles used for the studied sample are Visual-Spatial (29%, n = 10, followed by Kinesthetic (26%, n = 9), Logical-Mathematical (21%, n = 7), Interpersonal and Musical are used in equal amounts (9%, n = 3), as well as Linguistic and Intrapersonal (3%, n = 1). Five studies discuss more than one learning style; the rest only discuss one type of learning style.

The Allocation of Research Studies in Terms of State

The geographical allocation of authors is the subject of the second research query. **Figure 3** displays the categorisation of the chosen studies by country in which they were conducted. Although our systematic review just included publications published in English, the studies were conducted in diverse cultural contexts around the world. Most of the studies collected (n = 5) were

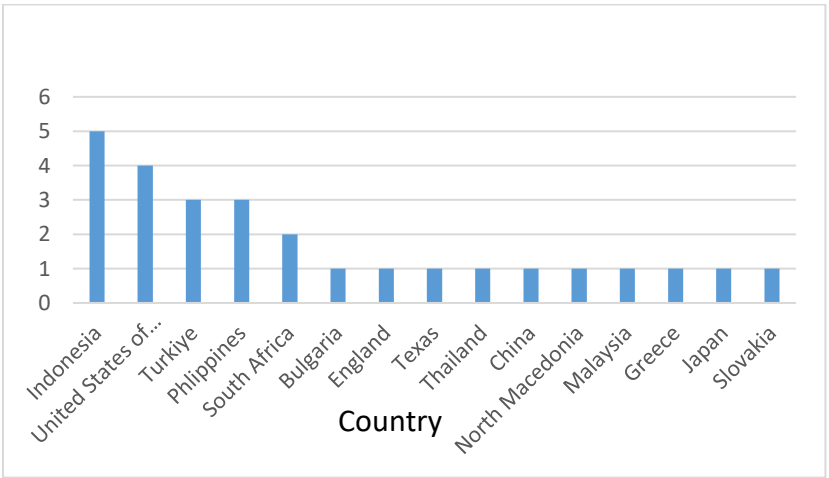

Figure 3. Distribution of research studies by country (Source: Authors' own elaboration)

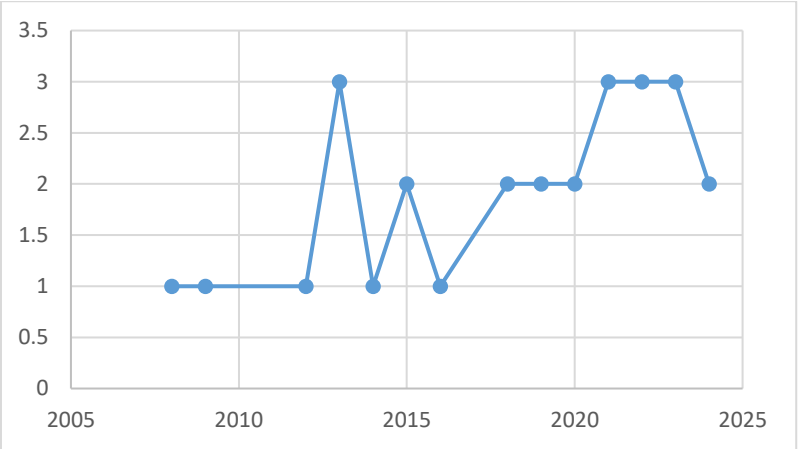

Figure 4. Distribution of research studies in terms of publication year (Source: Authors' own elaboration)

conducted in Indonesia, and (n = 4) were conducted in the United States. There were three articles in any of the following classifications: studies conducted in the Philippines and Turkey and two articles in studies conducted in South Africa.

In contrast, learning styles in mathematics education were the least discussed between academics in state such as the United Kingdom, Bulgaria, Texas, Thailand, China, Malaysia, North Macedonia, Greece, Japan, and Slovakia. As a result of these findings, it is possible that academics in Indonesia are becoming more and more interested in exploring learning styles in mathematics teaching. Thus, extra research on this topic is still needed in other states.

Distribution of Learning Styles by Year of Publication

The third research question relates to learning styles in mathematics based on the year of publication (**Figure 4**). Starting in 2008, people began to discuss learning styles in mathematics (n = 1). They followed in 2009 and 2012 with the same number (n = 1); in 2013, it began to increase with the number of publications (n = 3). The number of articles published in 2014 decreased (n = 1), then increased again in 2015 (n = 2). There was another decrease in 2016 (n = 1), while the number of articles in 2018, 2019, and 2020 was the same (n = 2). From 2021 to 2024, people began to focus on discussing learning styles in mathematics.

DISCUSSION

Our findings indicate that visual-spatial learning is the most frequently applied style in mathematics education, compared to other learning styles such as kinesthetic, logical-mathematical, interpersonal, musical, linguistic, and intrapersonal. These results align with Siler's (2015) assertion that visual representation can significantly enhance the understanding of brain and nervous system functions, as visual information is more easily processed and recalled by the brain. With ten papers addressing the impact of visual-spatial learning styles in mathematics, this approach is shown to have a notably positive influence.

Capinding (2021) underscores the influence of learning styles on students' academic achievement, instructors' pedagogical strategies, and parental approaches to education. This finding is in line with Mhlolo (2013), who suggests that employing diverse teaching methods in mathematics can effectively improve teaching quality and student achievement. Furthermore, addressing learning styles in educational environments can enhance academic performance (Altun, 2018). Thus, understanding learning styles is crucial for students and educators, as they directly influence how individuals absorb, process, retain, and recall knowledge. In addition to improving mathematical performance, learning styles can positively impact students' critical thinking skills (Evendi et al., 2022; Lubna et al., 2023).

Most researchers from the reviewed studies were from Indonesia and the United States, with only one from the United Kingdom, Bulgaria, Texas, Thailand, China, North Macedonia, Malaysia, Greece, Japan, and Slovakia. Given the unique learning preferences of each student, educators in Indonesia must account for various learning styles to meet diverse student needs (Tripathi et al., 2023). A significant body of research on learning styles has emerged in Indonesia due to its large student population, cultural diversity, and the ongoing need to raise educational standards. This understanding of learning styles helps explain why researchers in Indonesia and the United States are motivated to enhance students' mathematics abilities and achievements during the teaching-learning process. By understanding their learning styles, students can optimize their mathematics performance.

Özgen and Bindak (2012) highlight that differences in learning styles can shape students' perspectives on mathematics. Our findings regarding the publication year of studies on learning styles in mathematics show a significant increase in focus from 2021 onwards. Over the past five years, researchers have explored the effectiveness of learning styles, with most publications between 2021 and 2023 authored by researchers from Indonesia. Most of these studies suggest that addressing learning styles in educational settings can enhance academic performance. Gunčaga and Žilková (2019) emphasize that incorporating visualization techniques into mathematics teaching can improve elementary students' understanding of geometric principles. Despite this,

many authors publish on learning styles in fields beyond mathematics education, leading to a lower annual publication volume in this domain

The visual-spatial learning style remains the most employed method in mathematics due to the subject's reliance on spatial reasoning, particularly in geometry. Understanding geometric concepts often requires visualizing shapes and their relationships (Kospentaris et al., 2016). Visual learners are especially well-suited to this content given the challenges of visualizing geometric ideas. Students can develop connections between spatial reasoning skills, such as critical thinking, creative thinking, and multidimensional thinking, and other mathematical domains by fostering geometric thinking abilities. Furthermore, students with strong spatial reasoning skills tend to perform better in mathematics and are more likely to pursue careers in the field (Fowler et al., 2022).

Conversely, linguistic and intrapersonal learning methods are less utilized in mathematics education, as the subject is best understood visually, making verbal explanations less effective. Linguistic learning strategies are seldom chosen in mathematics because language can influence how we perceive visual information (Maier & Abdel Rahman, 2024). For instance, recognizing the linguistic differences between two items can help distinguish between them. Intrapersonal intelligence, associated with self-awareness, is less prevalent in mathematics learning because the focus is on applying mathematical concepts and problem-solvin (Perwira Negara et al., 2024; Utaminingsih et al., 2023).

Dornyei and Ryan (2015) note that learning styles are complex constructs with various definitions and classifications. As such, discussions on learning styles were sparse between 2014 and 2016, but interest in the topic began to grow in 2021 (Ishak, 2024). argues that learning styles represent one of the most significant affective factors distinguishing individuals and influencing how students engage with learning materials. By tailoring educational approaches to students' learning preferences, educators can make learning more accessible, efficient, and long-lasting (Aksoy & Üstündağ, 2023). Therefore, learning styles should be a central concern for educators and teachers.

CONCLUSIONS

An extensive search was conducted on the Scopus and Eric literature platforms to collect relevant information for this study. Finally, 27 papers were selected to investigate the use of learning styles in mathematics. The purpose of this study was to uncover what learning styles students use that can affect their achievement. This study also examined Table 3- the outcome of learning styles used in mathematics. The results of this study indicate that the use of learning styles in mathematics positively impacts student achievement.

Learning style is a way for students to understand the material given. At least seven learning styles are often used in learning mathematics. The most widely used learning style based on this study's results is visual-spatial. Visual-spatial learning style is often used because visual depiction can help improve understanding of brain and nervous system functions Siler (2015). Most studies consider using learning styles in mathematics to effectively improve learning outcomes, while others consider the opposite. This provides extra chances for future research to examine the underlying factors contributing to these results.

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