

A Systematic Review of Mathematics Achievement, Affect, and VA(R)K in the Conceptual Landscape of Learning Styles Research

Julia E. Calabrese

The University of Texas at Arlington
jecalabrese@gmail.com

Candace Joswick

The University of Texas at Arlington
candace.joswick@uta.edu

This study investigates the intersection of the VARK (Visual, Aural/auditory, Read/write, Kinesthetic) learning styles concept within the broader learning styles literature and its association with mathematics achievement and affect in K–12 settings. The learning styles concept, which characterizes students as having a preferred learning modality, is widely used and particularly adopted by educators and practitioners. However, the concept of learning styles is also scrutinized, citing issues with terminology and application. The notion that learning outcomes improve when instruction matches an individual’s preferred learning style has been described as a neuromyth, given the lack of empirical evidence. Using a systematic review process, we identified 5,064 references from 6 databases; 51 empirical, peer-reviewed articles indexed in major academic databases met our inclusion criteria and were analyzed for the incorporation of learning styles, learning styles instruments, and how VA(R)K was invoked within a conceptually varied learning styles literature in studies of student outcomes in mathematics. While results reveal a notable shift in where research has been conducted, no decrease in the number of publications over time was observed. Although some authors have suggested potential links between tailoring instruction to VA(R)K preferences and improvements in mathematics achievement and/or affect, the overall findings underscore conceptual inconsistencies across learning styles frameworks and a lack of robust empirical support. Educators are encouraged to use these findings to understand better how VA(R)K learning styles are positioned within a broader, conceptually inconsistent literature on learning styles in mathematics education and to prioritize evidence-based approaches over popular yet unsupported theories, such as learning styles.

Introduction

The concept of learning styles posits that “individuals differ regarding what mode of instruction or study is most effective for them” (Pashler et al., 2008, p. 105). Appearing in high-quality, peer-reviewed venues (e.g., Buiningtyas & Sutama, 2024) and highly regarded resources such as the National Council of Teachers of Mathematics lesson plans (e.g., “Light it Up” Illuminations lesson, NCTM, 2024), researchers have argued that students have a preferred learning style (e.g., Dunn et al., 1989). Furthermore, proponents assert that matching teaching styles to students’ learning styles is a crucial factor in student success (e.g., Cheshmazar et al., 2022; Halif et al., 2020).

Despite the popularity of the learning styles concept (Pashler et al., 2008), its utility remains controversial. Some have challenged the accuracy of the research supporting learning styles-based instruction. Kavale and LeFever (2007) identify critical issues in prior analyses, including sampling bias and interpretation of effect sizes. Pashler et al. (2008) criticized the lack of empirical validation in published research. Others have reported no evidence of a relationship between learning-style-specific instruction (Rogowsky et al., 2015) or learning-style-specific study strategies and students’ course performance (Husmann & O’Loughlin, 2018). Thus, some consider the efficacy of matching instruction to students’ learning styles a “neuromyth” (e.g., Newton & Salvi, 2020), a commonly held but inaccurate belief about how the mind and brain operate. Despite ongoing efforts to challenge it, the learning styles concept persists in contemporary research and educational practice, with implications for high-priority content areas such as mathematics.

Exploring learning styles in the context of K–12 mathematics education is critical due to the subject’s inherent demand for diverse cognitive processes. Mathematics encompasses a range of skills, from abstract reasoning and logical deduction to visual-spatial thinking and procedural fluency. Proponents of learning styles argue that tailoring instruction to students’ preferred modalities could enhance their engagement with mathematical concepts (e.g., Sheromova et al., 2020). For example, when learning mathematics, visual learners may benefit from charts and posters, whereas auditory learners may benefit from group discussions or self-talk (Midkiff & Thomasson, 1994). While the theoretical connection between learning styles and mathematical thinking presents intriguing possibilities, the continued presence of the concept, despite efforts to challenge it, warrants further exploration.

Literature Review

Fields such as psychology have repeatedly tried to understand how people learn, underscoring the widespread appeal of learning styles in education. In a 2004 review of the literature, Coffield et al. identified 71 models of “learning styles”. Although the underlying perspectives of these 71 models vary, the message is the same: students have preferred or optimal learning modalities (Pashler et al., 2008). Suppose learning style proponents are to be believed. In that case, individuals can and should identify their best learning modes, so that responsive instruction can match their most effective mode of learning. According to Landrum and McDuffie (2010), “The idea that people learn things differently has tremendous intuitive appeal” (p. 6). Unsurprisingly, the idea that learners should be matched with instruction delivered in their learning style was touted to improve teaching and learning effectiveness, thereby helping learning styles quickly pervade K–12 education (see Dunn & Griggs, 1998).

Among the many models contributing to the learning styles concept, Dunn and Dunn (1993), Felder and Silverman (1988), Fleming and Mills (1992), Kolb (1984), and McCarthy (1987) have each developed popular learning styles models. Each model focuses on distinct aspects of how students receive, process, and engage with information. While these models all emphasize tailoring instruction to individual needs, the VARK-specific model (Fleming & Mills, 1992) has gained traction in K–12 education (Papadatou-Pastou et al., 2020; Scott, 2010), perhaps for its simplicity and adaptability. Figure 1 displays each model.

Dunn and Dunn (1993)	Felder and Silverman (1988)	Fleming and Mills (1992)	Kolb (1984)	McCarthy (1987)
Evaluates students' preference for various stimuli during learning	Evaluates students' preference for type, modality, organization, processing, and progression of information	Evaluates students' preference for receiving and processing information	Evaluates students' process for perceiving and transforming information	Evaluates students' dimensions of perceiving and processing
• Environmental – Sound – Light – Seating – Temperature • Emotional – Motivation – Responsibility – Task persistence – Structure • Sociological – Independence – Authority • Physiological – Mobility – Intake – Time of day • Psychological – Analytical – Impulse/reflection	• Type of information – Sensory – Intuitive • Modality – Visual – Verbal • Organization – Inductive – Deductive • Processing – Active – Reflective • Progression – Sequential – Global	• Visual • Aural/auditory • Read/write • Kinesthetic	• Diverging • Assimilating • Converging • Accommodating	• Imaginative Learners • Analytic Learners • Common Sense Learners • Dynamic Learners

Figure 1. Popular Learning Styles Models

Fleming and Mills (1992), VARK

The VARK approach, credited to Neil Fleming (Fleming & Mills, 1992), breaks learning style preferences into four components: Visual (V), Aural (A, also known as auditory), Read/write (R), and Kinesthetic (K). Initially, VARK comprised only VAK (Fleming & Mills, 1992). Evidence of VAK-specific instruction dates back centuries, though it gained momentum in the 1970s, first within the special education community before ultimately reaching general education (Barbe & Swassing, 1979). As Fallace (2023) shows, however, the early VAK model emerged specifically from remedial reading research rather than from broad theories of general learning, and its later expansion into mainstream education represented a significant historical overextension. However, Fleming (1995) felt that having only three components was insufficient and separated the Visual component into Visual and Read/write to distinguish those who prefer graphics (Visual) from those who prefer text (Read/write).

Within the VARK model, its components describe how learners prefer to interpret and express information (VARK Learn Limited, 2024), though a learner may have a different approach to interpreting than to expressing information (Fleming, 1995). Learners with a Visual preference may favor the symbolic or graphic reception of information, such as interpreting diagrams, color-coding, or gestures during lectures. Those with an Aural/auditory preference may prioritize hearing information, such as listening to examples,

participating in discussions, and explaining to others. Learners with Read/write preference may favor lists, notes, and written statements. Finally, individuals with a Kinesthetic preference may prefer practical applications, laboratory participation, or multisensory experiences (Fleming & Mills, 1992). Learning styles researchers (e.g., Kharb et al., 2013; Rogowsky et al., 2020; VARK Learn Limited, 2024) argue that individuals may align with only one learning style, although most individuals exhibit multimodal preferences. According to VARK Learn Limited (2024), 66% of the 1,048,292 people who completed their questionnaire between September 2022 and August 2023 had multimodal preferences, and 31% had a four-part preference.

Although the VARK questionnaire is popular, there is limited evidence to suggest its effectiveness (Husmann & O'Loughlin, 2018; Moayyeri, 2015). For example, in a study by Husmann and O'Loughlin (2018), 426 postsecondary anatomy students completed the VARK questionnaire. The researchers found that students typically did not use VARK-aligned study strategies and that student performance in the class was not correlated with any VARK category. Further, according to Coffield et al. (2004), the psychometric rigor of learning style inventories, including VARK, is problematic, with most learning style questionnaires failing to meet minimum standards of reliability and validity.

While the VARK questionnaire is intended to uncover learner preferences, Fleming notes that VA(R)K itself is not a learning style and instead captures one of a complex web of preferences that constitute an individual's learning style (Fleming & Baume, 2006). Furthermore, Fleming and Mills (1992), in one of their seminal works, argue that learning styles are best used as a tool to empower students to adapt their behaviors to retain information most effectively. The official VARK Learn Limited (2024) website states that matching teaching styles to students' learning styles to improve learning is a misconception. They elaborate: "It is what students do that matters most, not what the teacher does and not how the learning materials are presented" (*How to use VARK to improve learning* section). This widespread misconception is partly rooted in the historical distortion Fallace (2023) identifies: educators and researchers later treated VAK/VARK as if it were designed for whole-class instructional matching, even though its early developers never intended it for such use.

The continued misrepresentation of VA(R)K suggests that many researchers are relying on secondary sources or generalized interpretations rather than engaging directly with Fleming and Mills' (1992) original work. Fallace's (2023) extensive archival history supports this point, showing that key figures such as Fernald, Orton, and Mills applied VAK principles narrowly to literacy interventions, rather than as universal learning-style prescriptions. Furthermore, the persistent misconception may be reinforced by popular education literature and teacher professional development programs that perpetuate inaccurate ideas (Cuevas et al., 2025; Newton & Salvi, 2020; Rogers & Cheung, 2020). The consequences of these misinterpretations extend beyond academic discourse to classroom practice. When educators structure lessons around matching teaching styles to students' perceived learning preferences, they may overlook evidence-based strategies that are more effective for student learning.

Learning Styles and Achievement, Affect

There is a long history of educators and researchers claiming that the use of the learning styles concept and specific learning styles models in classrooms can improve student

learning. In the meshing hypothesis, proponents claim that the best instruction is that in which teachers match their teaching style to students' prescribed learning preferences (e.g., Pashler et al., 2008). However, others have refuted these claims (e.g., An & Carr, 2017; Brown, 2023; Cuevas, 2015). This lack of consistency in findings has led to greater interest in answers; thus, researchers have continued to pursue these connections despite the controversy.

Several researchers have evaluated the meshing hypothesis and whether matching teaching styles to students' prescribed learning preferences can increase academic achievement. Repeatedly, there was a lack of evidence supporting this belief, specifically in terms of problem solving (Choi et al., 2009), retention (Cuevas & Dawson, 2018), test scores (Kozub, 2010), course grades (Massa & Mayer, 2005), or comprehension (Rogowsky et al., 2020). Furthermore, many have argued that holding this belief can be detrimental to students' learning by neglecting to improve their weaker skill sets (Rogowsky et al., 2020) and by embracing potentially harmful labels (Scott, 2010). Almost unanimously, researchers exploring this hypothesis have suggested that teachers should divert their attention to more reliable methods of instruction (e.g., Cook et al., 2009), such as using multimodal learning (Cuevas & Dawson, 2018), improving reading skills (Rogowsky et al., 2020), or instead encouraging students to modify their own approaches to learning (Choi et al., 2009; Rogowsky et al., 2020).

In a similar vein, researchers have argued that catering to students' learning preferences can improve affect. For example, Gilakjani (2012) argues that matching teaching and learning styles increases student motivation. However, this claim has also been challenged, with the effects being described as "negligible" (Choi et al., 2009, p. 945). Kozub (2010) found that regardless of students' learning preferences, there was no difference in students' reactions to the presentation of course content. Choi et al. (2009) further noted that any effects observed in students' perceived satisfaction are likely attributable to novelty and may diminish over time.

In addition to the concerns presented with the learning styles concept, connections to achievement and affect introduce further complications due to ambiguity. The term achievement has multiple interpretations, is used interchangeably with other terms (Mašková & Kučera, 2021), and encompasses various measures (Steinmayr et al., 2014). However, in education, achievement is generally understood to be a measure of proficiency in academic content (American Psychological Association [APA], 2018). As shown above, researchers evaluating the meshing hypothesis have explored achievement from multiple fronts. Similarly, Aquilina et al. (2024) reported in their systematic review that while "attitudes" are frequently assessed in mathematics research, the meanings of the term are inconsistent or not explicitly defined. However, affect is generally understood as feelings toward oneself and one's content (APA, 2018). This breadth of definitions and potential overlap among variables raises concerns about the accuracy of these concepts.

Building on this connection, a recurring belief in the literature is that attitude in mathematics predicts achievement (e.g., Dan'inna, 2017), leading to the erroneous assumption that improving affect will inherently improve achievement. In core content areas like mathematics, which is often considered difficult or tedious (Brown et al., 2008), improving achievement and/or affect is a widely desired goal. Thus, the possibility of improving in both areas offers teachers a hit-two-targets-with-one-arrow approach to teaching. However, this connection has also been questioned, indicating that improving

learning is a more complex process involving multiple factors (e.g., Mazana et al., 2019). This intuitive yet unsubstantiated idea has gained traction in many studies, despite the complex interplay between emotions, motivation, and cognitive outcomes.

Criticism of learning styles, studies. Although some researchers have claimed that matching instruction to students' learning styles is effective, others dispute these claims. For example, while Lovelace (2005) argued for matching students' Dunn and Dunn learning styles with complementary instruction, Rogowsky et al. (2015) investigated the effects of Dunn and Dunn's learning styles on college students across two instructional methods. They found no statistically significant association between learning style preference and instructional mode. Similarly, while Mašić et al. (2020) found significant differences in students' VAK learning styles and their GPAs, Taheri et al. (2021) found no significant relationship between the Kolb learning style model or the VARK learning styles model and students' GPAs. These are only a few instances that illustrate inconsistencies in findings from learning styles-oriented research.

Researchers have specifically critiqued the methodologies of various learning styles inventories and works supporting the learning styles concept. For example, the Kolb Learning Styles Inventory (1985) has been questioned for its validity and reliability (e.g., Garner, 2000; Willcoxson & Prosser, 1996). Leite et al. (2009) identified potential problems with the validity of the VARK Learning Styles Inventory (Fleming, 2001) due to poor item wording and the scale's scoring algorithm. Klitmøller (2015) argues that many findings from the literature used in Lovelace's (2005) meta-analysis were from unpublished sources that had not been peer-reviewed, and Kavale and LeFever (2007) contend that Lovelace (2005) misinterpreted effect sizes and did not account for sampling bias. Kavale and LeFever (2007) and Klitmøller (2015) question a meta-analysis documenting the effectiveness of Dunn and Dunn's learning style model. These methodological flaws highlight fundamental issues with the concept of learning styles.

To further refute claims supporting the learning styles concept, researchers have published literature reviews and meta-analyses that criticize it. For example, Coffield et al. (2004) examined 71 distinct learning style models, emphasizing their widespread use and conceptual diversity but critiquing the inconsistency in psychometric reliability and validity across models. Pashler et al. (2008) systematically evaluated the empirical evidence supporting the idea that aligning instruction with a learner's preferred style improves outcomes and concluded that no substantial evidence supports this claim. Olsen et al. (2022) examined the prevalence of learning styles in K–12 and higher education research, and references echoed Pashler et al.'s (2008) findings, emphasizing that while the concept of learning styles is compelling, there is a lack of measurable, replicable benefits in classroom settings. Further, in Cuevas's (2015) review, many of the related studies are strictly correlational rather than causal. Pashler et al.'s (2008) analysis also highlighted how the persistence of the learning styles concept might distract educators from adopting evidence-based strategies that have a greater impact on student outcomes. Other reviews, such as Husmann and O'Loughlin's (2018) study of postsecondary students, have highlighted the discrepancy between reported learning style preferences and actual study behaviors, further undermining the practical utility of the concept. These reviews collectively highlight the theoretical appeal of learning styles while raising concerns about methodological rigor and empirical evidence.

Considering this controversy, researchers such as Cuevas et al. (2023), Kirschner (2017), and Weale (2017) have published articles arguing that the learning styles concept is a neuromyth and advocating that teachers instead incorporate evidence-based practices into their instructional methods. Newton and Salvi (2020) offered a pragmatic systematic review, focusing on the persistence of the “learning styles neuromyth” despite these criticisms. Their findings suggest that while educators often report using learning styles in practice, this is primarily driven by intuitive appeal rather than robust evidence. Brown (2023) even went so far as to suggest a change in education students’ course requirements, replacing the learning styles concept with more evidence-based neuroscientific research, a notion similarly proposed by Cuevas et al. (2023). Despite numerous critiques, the concept of learning styles endures.

Study Purpose and Research Questions

The purpose of this study is to investigate the association between the VA(R)K-specific model, as situated within the broader learning styles literature, and mathematics achievement and affect in K–12 classrooms as presented in peer-reviewed, empirical articles published in English and indexed in major academic databases. We interpret VA(R)K not as an isolated construct but as situated within a broader, sometimes conceptually heterogeneous, literature on learning styles in K–12 mathematics. This study conceptually foregrounds the VARK model of learning styles, given its prominence in educational literature and practice. Because the VARK model evolved from the earlier VAK model, the two are often used interchangeably in research and practice; henceforth, we will refer to either as VA(R)K. By synthesizing findings from existing research, this study aims to evaluate the validity and utility of applying the VARK learning styles model in K–12 mathematics education (Papadatou-Pastou et al., 2020). These findings will illuminate whether tailoring instruction to learning style preferences affects important outcomes such as student achievement and affect, offering a fresh, content-specific perspective on this enduring yet contested concept.

Despite the widespread adoption of the learning styles concept and the VA(R)K model, limited empirical research provides a compelling argument for a connection between learning style preferences and improved educational outcomes. While the learning styles concept has been used to address the intersection of mathematics and learning disabilities (e.g., Joswick et al., 2023), prior literature and systematic reviews of learning styles research have not provided conclusive evidence linking learning style preferences to broader mathematics-specific outcomes. The extent to which tailoring instruction to a learning-style model enhances mathematical achievement and the effects of this approach remain underexplored. Therefore, this systematic review seeks to answer the following questions:

1. What are the characteristics of peer-reviewed, English-language, empirical articles including VA(R)K learning styles within the broader learning styles literature in K–12 mathematics research?
2. How have VA(R)K learning styles, as invoked within the broader learning styles literature, been associated with mathematics achievement and/or affect in K–12 mathematics research?

Materials and Methods

We used a systematic review process (Munn et al., 2018) to locate empirical articles published in peer-reviewed journals and indexed in major academic databases that examine

the relationship between learning styles and mathematics in K–12 education settings. A multi-step process, outlined below, was used to identify and select articles for inclusion and to extract data from them. Our analysis employed both descriptive statistics and content analysis.

Article Identification

Initial search. In July 2024, we searched six library databases available to us: ERIC (EBSCO), Education Full Text (HW Wilson), APA PsycInfo, SCOPUS, Web of Science, and Social Science Database. Using the search phrase “learning styles” AND “math*” (including quotation marks and asterisk), we identified 5,064 references (see Figure 2 for PRISMA diagram). This large volume reflects our intentional decision to avoid applying filters or limiters, thereby ensuring a broad scope that captures all potentially relevant articles for our study.

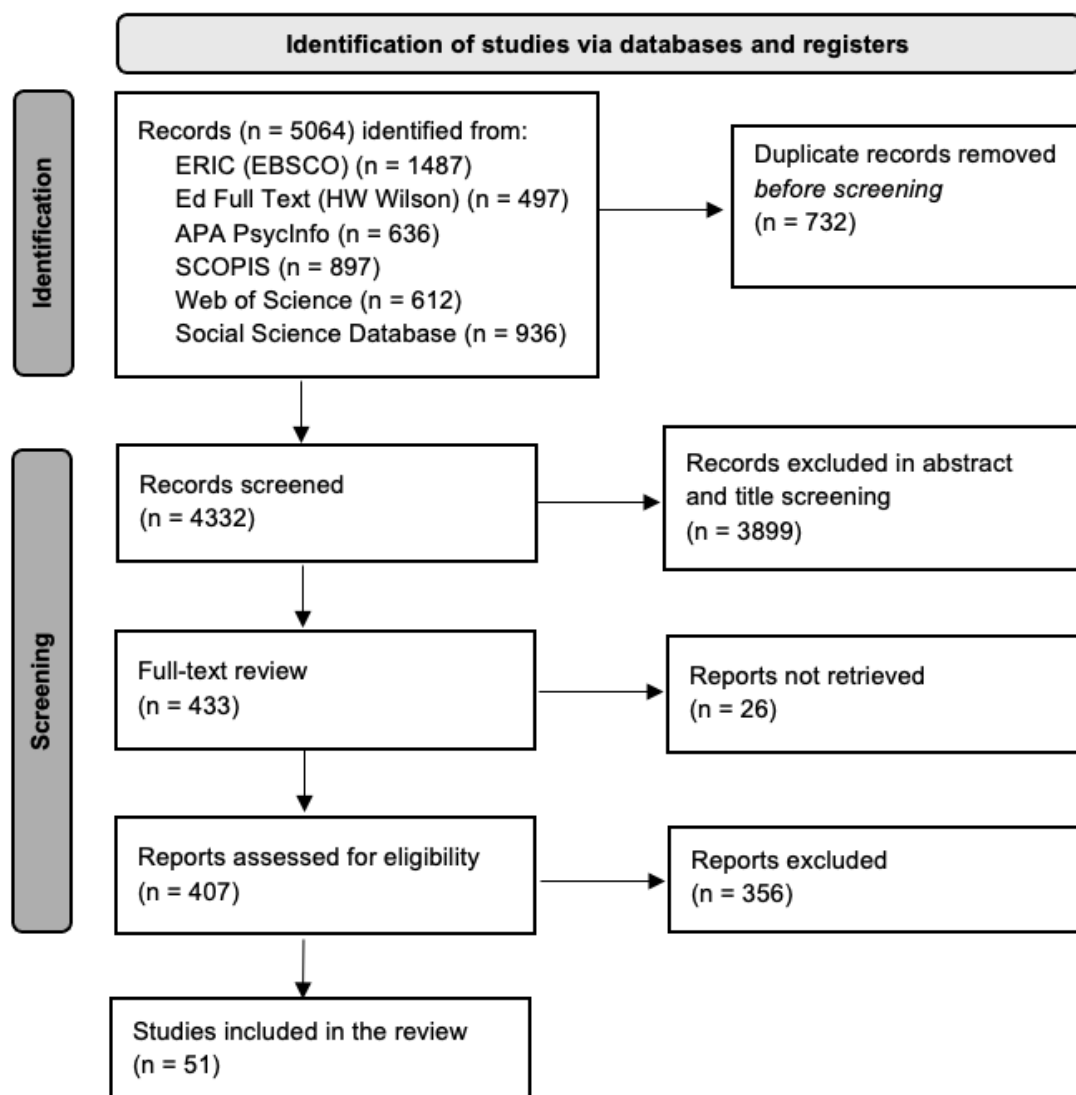


Figure 2. PRISMA Diagram

Abstract review. We uploaded all 5,064 references and abstracts to Rayyan (Ouzzani et al., 2016), an online tool for conducting systematic reviews. Rayyan flagged 1,315 potential reference duplicates, which we manually reviewed: 732 were confirmed and deleted, and 583 were retained, resulting in 4,332 references for screening. To refine our dataset, we applied the following inclusion criteria: (a) focus on VA(R)K learning styles due to their prevalence and longevity (Barbe & Swassing, 1979; Othman & Amiruddin, 2010), (b) peer-reviewed empirical studies (to moderate for quality) indexed in major academic databases, (c) K–12 mathematics education context, and (d) English language. Because the purpose of this review was to characterize how VA(R)K learning styles have been used in K–12 mathematics research and not to evaluate the matching hypothesis or determine instructional effectiveness, we did not limit inclusion to studies employing the experimental aptitude-by-treatment interaction design recommended by Pashler et al. (2009). Instead, we included the full range of empirical designs present in the K–12 mathematics literature. In cases where a non-VA(R)K learning style could not be determined, that is, the reference to learning styles was vague or otherwise did not explicitly indicate a different learning styles model, we did not exclude those articles.

Although this review centers on VA(R)K learning styles, which are prominent in educational discourse, the screening process intentionally retained studies that referenced learning styles in K–12 mathematics without clearly specifying a particular model. This decision reflects the reality that many empirical studies invoke VA(R)K terminology alongside, or interchangeably with, other learning styles frameworks. Consequently, the corpus analyzed here should be understood not as a review of strictly VA(R)K-validated studies, but rather as a review of learning styles research in K–12 mathematics in which VA(R)K serves as a dominant, though inconsistently operationalized, reference point. This distinction is critical for interpreting the findings and conclusions that follow.

A team of three researchers reviewed abstracts in blinded pairs. Rayyan flagged conflicts, which were resolved through consensus; 3,899 references were excluded.

Full-text review. Following abstract review, 433 articles proceeded to full-text screening. Despite extensive efforts, 26 were unavailable, leaving 407 for review. Of these, 356 were excluded based on the inclusion criteria described above, leaving 51 articles for data extraction.

Data extraction. Using Covidence (Veritas Health Innovation, 2024), we developed a custom extraction template (see Figure 3) to code data from the 51 included articles. We recorded the study location and publication year to identify temporal and spatial patterns. To assess achievement-related outcomes, we included any terms referencing math proficiency (e.g., “grades”, “performance”, “test scores”). For example, we captured references to “attitude”, “interest”, or “perception” (see Appendix B). The depth of the learning styles theory discussion was rated on a three-point scale adapted from Kumasi et al. (2013): minor (mentioning the learning styles concept with no elaboration), moderate (brief elaboration but no analysis of the concept), and major (the concept was tested or developed; see Appendix B). Two team members independently coded each article. Discrepancies were reviewed and resolved through discussion. The final dataset is provided in Appendix A.

Citation		
Author Name(s)	Journal Name	Publication Year
Study Location		

<i>Continent, if specified by authors. Turkey and Cyprus are separate since they each span two continents. Select one:</i>							
Africa	Asia	Australia	Cyprus	Europe	North America	Turkey	Did not specify
Study Parameters							
<i>Achievement and/or affect study outcome(s) the author(s) intended to measure. Select all that apply.</i>							
Achievement				Affect			
Study Instruments or Measures							
<i>Instruments or measures of the study parameters (achievement and/or affect) and/or learning styles outcomes. Select all that apply and note the associate study parameter.</i>							
Classwork	Class grade	Author's instrument		Outside author's instrument		Unstated	
Learning Style(s) Mentioned							
<i>Mentions of VA(R)K-specific learning style(s), VARK as a whole, non-specific learning styles, or additional specific learning styles beyond VA(R)K. Select all that apply.</i>							
Aural/auditory	Kinesthetic	Read/write	Visual	VARK (as a whole)	Additional learning styles	Non-specific learning styles	
Learning Style Developer(s) Mentioned							
<i>Select all that apply.</i>							
Dunn and Dunn (1993)		Felder and Silverman (1988)		Fleming and Mills (1992)	Kolb (1984)	McCarthy (1987)	Other
Depth of (Learning Style) Theory Discussion							
<i>Theory talk adapted from Kumasi et al. (2013), to describe the extent to which learning styles concept was incorporated into the study. Select one.</i>							
Major			Minor		Moderate		

Figure 3. Data Extraction Template

Data Analysis

We conducted descriptive analyses and created data displays to address our first research question: *What are the characteristics of peer-reviewed, English-language, empirical articles including VA(R)K learning styles within the broader learning styles literature in K–12 mathematics research?* This enabled us to summarize key features of the articles and identify studies for further analysis. In all cases, two researchers independently coded and resolved discrepancies through discussion to ensure 100% agreement.

Analysis of learning styles models. Given the range of learning styles models, we analyzed each article for citations to learning style models and for the use of learning style inventories. For each study, we documented the instrument used to measure learning styles, including its name, description, citations, and whether it was cited or author-developed. We then calculated descriptive statistics on these features. We listed each style mentioned (e.g., Visual, Aural/auditory, Read/write, Kinesthetic), coded them descriptively (Saldaña, 2013), and generated summary statistics.

Analysis of achievement. To explore the connection between learning styles and achievement, we analyzed articles that included “achievement” in the search terms. We used attribute coding (Saldaña, 2013) to classify instruments by name, type, and citation, then themed them for quantification. We recorded achievement-related terms used to describe achievement (e.g., grades, scores) and calculated their frequency across articles.

Analysis of affect. Following a parallel approach to achievement, we examined affect-related data, including measurement instruments and terminology. We applied the same codes from the achievement instruments and noted exceptions, reporting frequencies for each category. We catalogued all affect-related terms according to the APA (2018) definition, then computed the frequency of each term and the number of affect-related terms used per article.

Linking learning styles to other parameters. To address our second research question, “How have VA(R)K learning styles, as invoked within the broader learning styles literature, been associated with mathematics achievement and/or affect in K–12 mathematics research?” we conducted content analysis (Krippendorff, 2018) of relevant studies. Again, in all cases, two researchers independently coded and resolved discrepancies through discussion to ensure 100% agreement. We filtered articles that assessed both learning styles and achievement, then used magnitude coding (Saldaña, 2013) with the categories: positive, negative, neutral, does not link, and other (see Appendix B). These captured the authors’ conclusions regarding instructional alignment and achievement outcomes. Using the same coding scheme, we examined studies that assessed both learning styles and affect, noting whether and how the authors discussed their relationship.

Results

Study Location Over Time

Given the influence of Pashler et al.’s (2008) critique of learning styles, we analyzed trends in the geographic distribution of related publications before and after 2008. As interest in learning styles gained momentum in the 1970s, so did publications exploring their connection to mathematics education, initially concentrated in Europe and North America. Before 2008, all published articles came from North America (9 studies, 60.0%), Europe (5 studies, 33.3%), and Cyprus (1 study, 6.7%). Our analysis shows a marked decrease in research from North America and Europe following 2008, with just four studies combined from these regions through July 2024. In contrast, research from Asia (15 studies, 41.7%), Turkey (9 studies, 25.0%), and Africa (2 studies, 5.6%) increased, collectively accounting for 72.3% of publications after 2008. These findings suggest a notable geographic shift in research interest in learning styles (see Figure 4).

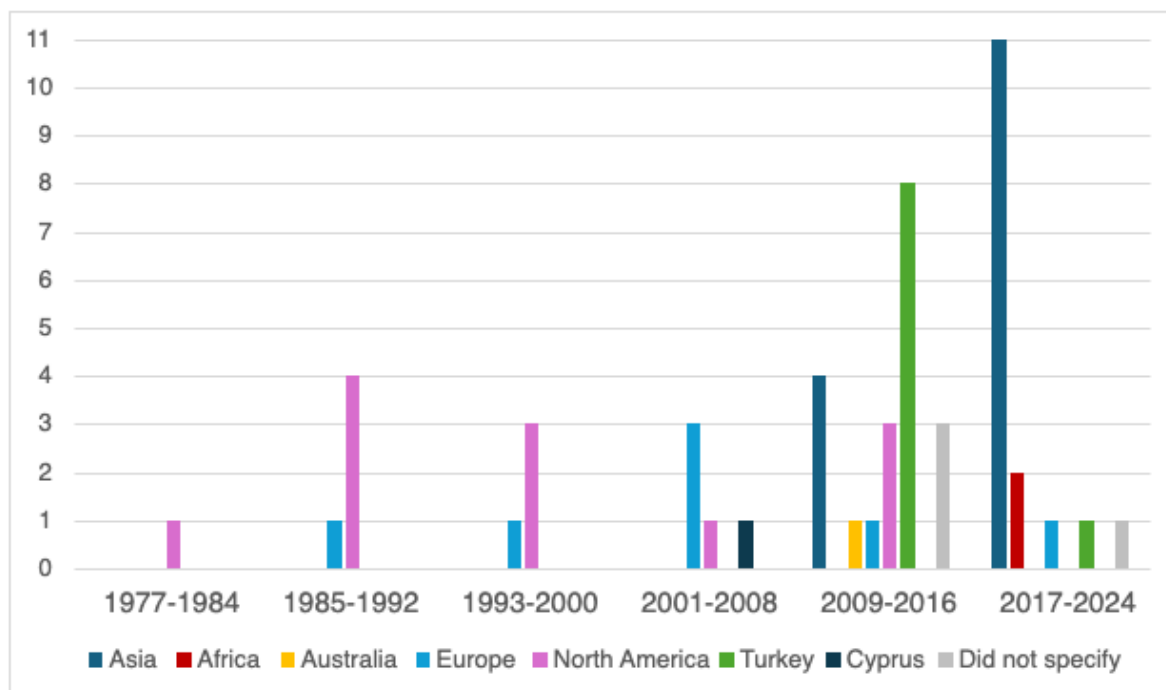


Figure 4. Publications by Location Over Time

Note. Turkey and Cyprus were treated as their own locations due to their transcontinental identities.

Theoretical Foundations and Implementation of Learning Styles in Research

Depth of (learning styles) theory discussion. The extent to which studies engaged with the theoretical foundations of the learning styles concept varied considerably. We evaluated all 51 articles for the depth of their inclusion of the concept of learning styles throughout the paper. Thirteen articles (25.49%) demonstrated minor depth of engagement ($n = 7$ through 2008 and $n = 6$ after 2008), often treating learning styles as an assumed or unquestioned concept. In these cases, learning styles were frequently assumed to be valid without discussing the substantial body of research that has challenged their efficacy. In addition to these patterns in the mathematics education literature, our findings align with broader research on why unsupported ideas, such as learning styles, persist in schools. Willingham (2009, 2018) has argued that teachers are often motivated consumers of research but face considerable barriers in accessing, interpreting, and applying empirical evidence. As a result, ideas that appear intuitive, actionable, or aligned with teachers' professional commitments, such as tailoring instruction to presumed learning styles, are likely to be adopted even in the absence of supporting research.

The persistence of VA(R)K in the studies we reviewed may therefore reflect not only patterns in the scholarly literature but also the broader landscape in which teachers and researchers operate, one in which myths can be repeated, institutionalized, and embedded into practice despite longstanding evidence to the contrary. For example, Lindh and Holgersson (2007) mention "learning styles" only once without further elaboration or integration in the remainder of the manuscript. Seven articles (13.73%) demonstrated a moderate depth of engagement. In one such study, Boaler (1998) briefly explores a potential link between gender and learning styles, though the study's use of the concept is unclear. In

both the minor- and moderate-depth cases, authors left much to be desired in terms of specificity and rigor in their treatment of the concept of learning styles.

In contrast, in articles with a high level of theoretical depth (31 articles, 60.78%, $n = 4$ through 2008 and $n = 27$ after 2008), authors examined the origins and evolution of learning styles, critiqued their conceptual foundations, or situated their use within a broader educational or psychological framework. In these studies, authors often justified instructional approaches by drawing on specific theoretical models and offered more nuanced discussions of how learning styles relate to cognition and learning outcomes. For instance, Gülen and Özkan (2013) used their analysis of students' perceptions of success, along with their designated learning styles, to argue that instructors should administer learning style inventories and take the results into account when designing lessons. Studies that critically engage with the learning styles construct provide stronger methodological justification and contribute to a more informed academic discourse. Conversely, those who rely on implicit assumptions risk reinforcing misconceptions and hindering pedagogical advancement. Detailed scores for each article are in Appendix A.

Learning style developer(s) mentioned. The included articles cited a wide variety of models and their developers. The five most frequently cited developers were Kolb (e.g., Kolb, 1984), Dunn (e.g., Dunn & Dunn, 1993), McCarthy (e.g., McCarthy, 1987), Felder (e.g., Felder & Silverman, 1988), and Fleming (e.g., Fleming & Mills, 1992). Although inclusion in the review required some engagement with the VA(R)K framework or could otherwise not be interpreted as another learning style model, only five studies explicitly cited Fleming's work (Bosman & Schulze, 2018; Danişman & Erginer, 2017; Hauptman, 2011; Shirvani, 2016; Sriphai et al., 2011), though many more mentioned the VA(R)K model or its individual styles. Dunn's work appeared most frequently, cited in 24 articles. Additional developers cited in multiple articles include Honey and Mumford (e.g., Honey & Mumford, 1992) and Kozhevnikov (e.g., Kozhevnikov, 2007). Notably, nearly half of the studies (23 articles) either cited alternative, non-repeating developers or referred to learning styles without citing any specific model.

Many articles mentioned multiple developers: 14 cited at least two of the five most frequently mentioned developers, while 10 cited at least three. The rationale for this varied. Some authors acknowledged the existence of multiple models but focused their study on a single framework (e.g., Sriphai et al., 2011; Shirvani, 2016). Others demonstrated conceptual overlap in their instrumentation. For example, Bosman and Schulze (2019) and Yilmaz (2016) incorporated elements from both Fleming's VA(R)K and Dunn's models. Additionally, a few studies included VAK-style items in their instruments without citing a developer (e.g., Rahman & Ahmar, 2017). Collectively, these patterns suggest that VA(R)K was rarely treated as a distinct theoretical framework; instead, it appeared within a broader, conceptually overlapping discourse on learning styles.

Learning styles and learning styles inventories. Of the 51 articles reviewed, 32 (62.7%) assessed students' VA(R)K learning styles. However, the methods of assessment varied considerably, ranging from formal surveys to teacher- or author-based evaluations. In addition, the specific learning style categories included in these assessments were not consistent across studies.

Between 26 and 30 distinct instruments were used to evaluate students' learning styles, with only two appearing in more than one study: Dunn et al.'s (1985) Learning Style Inventory (used by Geiser, 1999; Tully et al., 2006) and Gökdağ's (2004) Learning Style Inventory (used by Özyurt et al., 2012, 2013, 2014). All other instruments were either unique to a single study or not cited at all. This substantial variation in instruments raises concerns about the consistency and validity of findings across the literature, as most studies relied on untested, unvalidated, or insufficiently described tools. A detailed breakdown of instrument usage is provided in Table 1.

Across the various instruments, authors drew between seven and ten different learning style models. Recall that the articles were included in the review if they referenced VA(R)K learning styles or unspecified learning styles, not other non-VA(R)K frameworks; therefore, it is unsurprising that the most frequently assessed learning styles were VA(R)K. Of the 32 studies that measured participants' learning styles, 22 assessed some variation of the VA(R)K model. This included studies that focused exclusively on VAK/VARK (e.g., Capinding, 2021; Danişman & Erginer, 2017), as well as those that expanded the framework by adding dimensions—such as Bosman and Schulze (2018), who included Individual and Group learning styles alongside VARK.

Table 1
Learning Styles Instrument Count by Article.

Instrument category	Number of articles
Dunn et al.'s (1985) Learning Style Inventory	2
Gökdağ's (2004) Learning Style Inventory	3
Instrument created by presenting author	7
Other instrument created by outside author	16
Uncited instrument	4

Only two studies used the Dunn and Dunn model (Tully, 2006; Geiser, 1999), while five others employed unique models not repeated elsewhere in the dataset—for instance, Aydin (2016) used Kolb's Learning Styles Inventory. In three cases (Birrell, 1985; Ting, 2016; Copenhaver, 1979), the specific learning style model was not identified, leaving open the possibility that these studies relied on models already cited or entirely different ones. The distribution of the learning style models used appears in Figure 5.

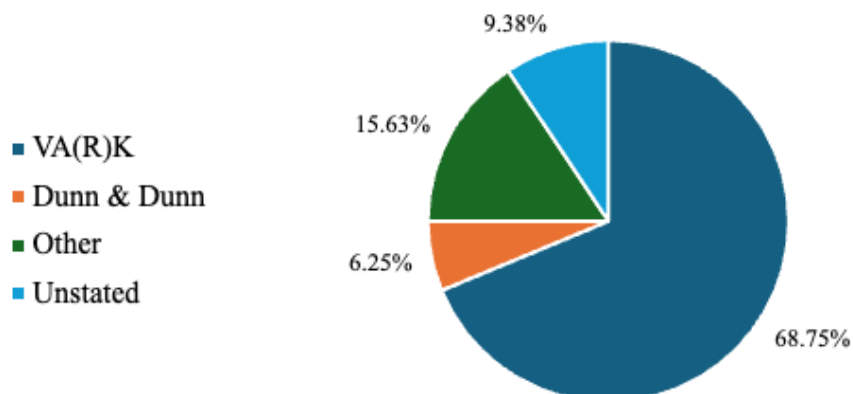


Figure 5. Distribution of Learning Styles Included in Inventory

This variability in instruments and theoretical references further indicates that the literature does not constitute a coherent body of VA(R)K-specific research, but rather a sometimes heterogeneous field of learning styles in which VA(R)K terminology is inconsistently operationalized.

Achievement

Of the 51 articles reviewed, 43 measured student achievement in some form; however, there was considerable variation in both the terms used to define achievement and the types of instruments employed to assess it.

In most cases, the achievement instrument was developed by the study's author(s) or co-created with the course instructor at the site where the research was conducted. Many studies also used instruments developed by external authors; however, none of these instruments were used in more than one article, indicating inconsistent use across studies. In some instances, achievement was measured through course performance metrics such as grades or completed coursework. Notably, two studies (Hannafin & Scott, 1998; Tran et al., 2020) employed multiple instruments to assess achievement. A summary of the types and distribution of achievement measures is presented in Table 2.

Table 2
Use of Achievement Instruments

Instrument Type	Count
Author's instrument	20
Outside Author's Instrument	15
Grade	6
Classwork	2
Unstated instrument	2

Among the 43 articles that measured achievement, we identified 25 distinct terms used to describe or represent the concept. Of these, 33 articles explicitly used the term "achievement". Other frequently used terms included "performance" (14 articles), "scores" (6), "understanding" (5), and "grades" (4). The remaining terms appeared in three or fewer articles. Several studies employed multiple terms interchangeably. For instance, Bosman (2018) referred to "achievement," "performance," and "learning" within the same manuscript.

Linking learning styles to achievement. We found that 26 articles both measured achievement and administered a learning style inventory. However, as previously noted, the wide variety of inventories used across studies raises concerns about the consistency and validity of the findings. Of these 26 articles, only 4 did not attempt to explore a connection between learning styles and achievement (Hadfield et al., 1992; Mann, 2014; Sulisawati et al., 2019; Zentall & Smith, 1992). The remaining studies reported either a positive relationship, a significant correlation between learning styles and grades, or no relationship (e.g., Baltacı et al., 2016). Notably, no study reported a negative relationship (i.e., that aligning teaching to students' learning styles resulted in lower mathematics performance).

Interestingly, interest in measuring this potential relationship increased following the publication of Pashler et al. (2008). Before 2009, only five articles examined both achievement and learning styles. Of those, three (60.0%) reported a positive association,

whereas two (40.0%) included both measures but did not examine the relationship. Since 2009, 21 additional articles have addressed both constructs, 19 of which explicitly tested for a relationship. Among these, 12 studies (63.2%) reported a positive connection, while 7 (36.8%) found no link (see Table 3).

Even among studies that reported positive linkages, the nature of the relationship varied. Some studies emphasized a general alignment between teaching styles and students' learning styles (e.g., Ozerem & Akkoyunlu, 2015; Ting & Tarmizi, 2016). Others explored more specific associations, such as links between learning styles and achievement outcomes (e.g., Danişman, 2017) or compared achievement levels across students with different learning styles (e.g., Ardianik et al., 2020; Capinding, 2021). Thus, the explanations for any positive linkage vary across studies.

Table 3
Linkage Between Learning Styles and Achievement Before and After 2008

2008 and Before			2009 and Beyond		
Birrell et al.	1985	Positive	Hauptman and Cohen	2011	Neutral
Hadfield et al.	1992	Does not link	Sriphai et al.	2011	Positive
Zentall and Smith	1992	Does not link	Shahrill et al.	2013	Positive
Geiser	1999	Positive	Mann	2014	Does not link
Tully et al.	2006	Positive	Özyurt et al.	2014	Neutral
			Ma and Ma	2014	Positive
			Ozerem and Akkoyunlu	2015	Positive
			Rahman et al.	2016	Neutral
			Yilmaz et al.	2016	Neutral
			Baltaci et al.	2016	Positive
			Ting and Tarmizi	2016	Positive
			Shirvani	2016	Positive
			Rahman and Ahmar	2017	Neutral
			Danişman and Erginer	2017	Positive
			Bosman and Schulze	2018	Positive
			Sulisawati et al.	2019	Does not link
			Virgana	2019	Neutral
			Ardianik et al.	2020	Positive
			Capinding	2021	Positive
			Santos et al.	2022	Neutral
			Sayed et al.	2022	Positive

Affect

More than one-third of the included studies (20 out of 51) examined affective outcomes. Details on which specific studies addressed the effect are provided in Appendix A. Among these studies, there was considerable variation in both how affect was measured and the aspects of affect that were investigated. Additionally, several authors have examined the relationship between learning styles and affect, and we discuss their findings accordingly.

In terms of the creation of instruments used to measure affect, there was an even split between instruments created specifically for the presenting study and those designed before the study (See Appendix A). One article (Gülten & Ökan, 2013) contained an instrument that was pre-existing and marked as the author's instrument, as one of the authors on the paper was also an author of the original paper where the instrument was first presented. Another article (Wan Hussin et al., 2023) used an existing instrument developed by an

external author. It was labelled as such, despite the instrument having been slightly modified to meet the study’s needs.

We found that at least ten different terms were used to indicate affect. By far, the most prominent term used was “attitude”, which occurred in twelve of the twenty articles examining affect. Other terms that occurred more than once were “motivation” (3), “anxiety” (2), and “opinion” (2). The following terms were used in only one article: beliefs, procrastination, self-concept, self-efficacy, self-esteem, and self-perception. It was not uncommon for authors to use multiple terms to describe affect within the same article, and, in any case where multiple terms were used, one of them was attitude. For example, Sriphai et al. (2011) used the terms “attitude”, “self-concept”, and “motivation”, while Özyurt et al. (2013) used “attitude” and “opinion”.

Linking learning styles to affect. Fourteen of the articles that measured affect also included a learning style inventory (see Table 4). Of these, eight explicitly explored the potential relationship between instruction tailored to students’ learning styles and changes in student affect. All three studies published prior to Pashler et al.’s (2008) critique reported positive associations. For instance, Geiser (1999) found higher attitude scores among students whose learning styles were accommodated.

Following Pashler et al.’s critique, four additional studies examined this relationship. One study (Özyurt et al., 2012) reported ambiguous or inconclusive findings. The other three studies (Aydin, 2016; Gülten & Özkan, 2013; Wan Hussin et al., 2023) identified more specific patterns. For example, Aydin (2016) found that only students with learning styles demonstrated “high” or “very high” attitudes toward mathematics. Similarly, Gülten and Özkan (2013) reported that students who self-identified as “very successful” in mathematics scored significantly higher on the auditory dimension. Wan Hussin et al. (2023) observed that students with specific learning styles, specifically visual and kinesthetic, were more likely to exhibit academic procrastination.

Table 4

Linkage Between Learning Styles and Affect Before and After 2008

2008 and Before			2009 and Beyond		
Copenhaver	1979	Positive	Sriphai et al.	2011	Does not link
Hadfield et al.	1992	Does not link	Özyurt et al.	2012	Unclear
Geiser	1999	Positive	Özyurt et al.	2013	Does not link
Tully et al.	2006	Positive	Gülten and Özkan	2013	Specified connections
			Özyurt et al.	2014	Does not link
			Ting and Tarmizi	2016	Does not link
			Aydin	2016	Specified connections
			Capinding	2021	Does not link
			Santos et al.	2022	Does not link
			Wan Hussin and Mohd Matore	2023	Specified connections

Taken together, these descriptive results position VA(R)K less as a unified object of empirical study and more as a recurring reference point within a conceptually fragmented literature on learning styles in K–12 mathematics.

Discussion

Examining studies on the learning styles concept, particularly the VA(R)K model, and its association with mathematics achievement and/or affect in K–12 settings, reveals a continued reliance on the framework, despite sustained critiques. Although foundational challenges to the validity of learning styles have been well documented (e.g., Pashler et al., 2008), and more recent critiques continue to surface (e.g., Brown, 2023; Weale, 2017; Wiliam, 2016), research also points to the persistence of proponents (e.g., Olsen et al., 2022; Joswick et al., 2023). This review suggests that, despite many researchers’ best efforts to lay this zombie concept to rest, the myth of learning styles remains alive and well within K–12 mathematics education. Accordingly, the body of literature reviewed here is best understood not as a coherent corpus of VA(R)K-specific research, but as a broader learning styles discourse in which VA(R)K is frequently invoked amid conceptual inconsistency.

Geographic Trends in Learning Style Research in Mathematics Classrooms

Although the concept of learning styles continues to appear in publications, our analysis revealed distinct geographic trends in the distribution of English-language research on the relationship between learning styles and mathematics. Before 2008, most studies were conducted in North America and Europe. However, following the publication of Pashler et al.’s (2008) critical review—which may have contributed to waning interest in these regions—there was a marked increase in studies from Asia, Turkey, and Africa. This geographic redistribution aligns with patterns noted in other literature reviews (e.g., Olsen et al., 2022).

These shifts raise important questions about the decline in North American and European publications and the increase in publications elsewhere. One potential explanation is that the lack of empirical support for learning styles has diminished scholarly enthusiasm for conducting or publishing research on these topics in these regions. Our analysis of theoretical depth bolsters this interpretation. For instance, through 2008 (our marker year based on Pashler et al.), only 4 of 15 articles were categorized as offering a major engagement with learning styles theory, while 7 were considered minor. In contrast, of the 36 articles published after 2009, 27 were categorized as major and only 6 as minor. Thus, while research output in North America and Europe decreased, the overall number of publications increased, and there was a discernible shift in the depth and manner in which learning styles were incorporated.

(Mis- or Ill-formed) Conceptualizations of VA(R)K

Our study focused on VA(R)K-type models and the general learning styles literature, in which the VA(R)K model dominated, or in which no specific learning styles model or perspective could be determined. We found that the misinterpretation of VA(R)K—not as a learning preference intended to empower students, but as a set of formulae for teaching styles—has significant implications for both research and practice. For example, the misalignment between citations (favoring Dunn and Dunn over Fleming and Mills, for example) suggests a conflation of different learning styles models, further complicating efforts to assess their validity critically; the few references to Fleming and Mills (1992) and the lack of accurate depiction of the intent of the VA(R)K framework were surprising.

“Links” between learning styles, achievement, and affect. Our analysis found mixed results regarding the relationship between learning styles and achievement or affect. While some authors reported positive links (e.g., Birrell et al., 1985; Sriphai et al., 2011), others failed to confirm them (e.g., Santos et al., 2022; Ting & Tarmizi, 2016). Furthermore, even among those making similar decisions (i.e., all positive), the explanations for those decisions varied substantially across studies. Thus, the combination of variation in outcomes (e.g., positive vs. neutral) and variation within similar outcomes (i.e., positively linking one type to greater achievement vs. positively linking matching styles to achievement) warrants concern. This pattern reinforces the interpretation that VA(R)K functions less as a stable theoretical construct in mathematics education research and more as a loosely referenced element within a broader, conceptually unsettled learning-styles tradition.

Issues with Learning Styles Instruments

The wide variety of learning style inventories used across the studies raises important concerns about the consistency, validity, and theoretical alignment of the findings. This echoes prior research that has criticized the concept of learning styles. Specifically, some commonly used learning styles instruments, including the VA(R)K questionnaire, have been questioned for poor psychometric properties (Coffield et al., 2004; Kavale & LeFever, 2007; Leite et al., 2009; Pashler et al., 2008; Willcoxson & Prosser, 1996).

Of the 26-30 distinct instruments identified, only two were repeated, suggesting that most studies relied on unique, untested, or unvalidated instruments. This lack of standardization poses a challenge for comparing findings across studies, as the tools used may not reliably measure the same constructs. While Dunn et al.’s Learning Style Inventory (1985; 2000) and Gökdag’s Learning Style Inventory (2004) both appeared more than once, the remaining instruments were either uncited or created by the authors of the studies, suggesting that they may not have been widely recognized or peer-reviewed. Further, the lack of evidence of test-retest reliability for these instruments suggests that a student may identify under one learning preference and then identify under a different one if retested. This lack of rigor limits the generalizability of the results and underscores the need for more robust, standardized instruments in future research.

Additionally, our analysis revealed that many studies accepted the learning-styles premise as valid without interrogating its empirical foundations. This uncritical adoption is problematic because it positions learning styles as an established, effective mechanism for improving achievement or affect, even though the matching hypothesis has not been empirically confirmed. When research designs assume, rather than test, the core theoretical claim, the validity of subsequent findings is undermined from the outset. These concerns are compounded by the wide variation in instruments used across studies, many of which were teacher- or researcher-created and lacked evidence of reliability or validity. Together, these patterns indicate that both conceptual and methodological assumptions in the learning styles literature warrant substantial caution.

Another major concern is the lack of theoretical alignment between the instruments used and the learning styles frameworks they claim to measure. More specifically, the choice of learning style instruments often did not align closely with the stated research goals, potentially creating a mismatch between the study’s focus and the instruments used. For instance, studies aimed at assessing VA(R)K learning styles did not always use instruments specifically designed to measure those styles, which could obscure the clarity and focus of the research. Furthermore, some authors used instruments that combined elements from

multiple models (Bosman & Schulze, 2019; Yilmaz, 2016). Finally, many studies reference broad learning styles concepts but then employ inventories without clear theoretical justification for their selection (e.g., Copenhaver, 1979; Rahman & Ahmar, 2017). This inconsistency undermines the validity of research findings and suggests that learning styles are often treated as a premise rather than as a rigorously examined construct. This raises questions about the internal consistency of the studies and the validity of the instruments used to assess the intended learning styles.

Considerations and Limitations

One limitation of our study is that we did not conduct a meta-analysis, which would require a more comprehensive review of quantitative studies. Additionally, we excluded non-English-language studies, as articles written in languages other than English without a readily locatable English translation were excluded. This restriction may have limited the scope of our findings, but the selected articles still yielded data saturation regarding the persistence of the learning styles concept. Thus, the results of the discarded articles are not included in our findings. However, our findings show substantial variation in analyses and results across manuscripts, suggesting that our selected articles provide data saturation regarding the persistence of the learning styles concept.

We also focused only on empirical articles that mentioned learning styles, but not all of these studies directly addressed a learning styles model. Some merely referenced the concept without engaging with it substantively. This approach was intentional, as we sought to understand the extent to which the “neuromyth” of learning styles persists in the literature, even in studies that did not make learning styles a primary focus. We included the depth of the theory analysis to help readers assess the rigor, or lack thereof, of each included piece. Thus, the primary contribution of this review is not simply documenting outcomes associated with VA(R)K, but clarifying the conceptual conditions under which VA(R)K appears—namely, within a fragmented and inconsistently theorized literature on learning styles in K-12 mathematics.

One key limitation of our study is the implicit division of the learning styles literature into a “before” and an “after” period, as in Pashler et al. (2008). Their review is often cited as a turning point in the learning styles debate, as it provided a strong critique of the lack of empirical evidence supporting the effectiveness of tailoring instruction to learning styles. Furthermore, this critique is often cited in more recent critiques of the learning styles concept (e.g., Newton & Salvi, 2020). However, this division may be somewhat arbitrary, as skepticism about learning styles predates Pashler et al. (2008), and some post-2008 studies continue to endorse the learning styles framework without addressing the critiques raised. Furthermore, treating Pashler et al. (2008) as a definitive watershed moment may oversimplify the evolution of the discourse. While their work was influential in shifting some perspectives, the persistence of learning styles in educational research and practice suggests that resistance to their conclusions remains. Future studies should consider a more nuanced examination of how and why learning styles continue to be promoted despite empirical challenges, rather than assuming a strict “before” and “after” effect.

Additionally, the timeframe of our study may influence how we interpret trends in the literature. If earlier studies were more accepting of learning styles without question, and later studies are more critical, this may reflect broader shifts in educational psychology rather

than a direct response to a single publication. More research is needed to trace the interplay between empirical critiques, policy shifts, and continued advocacy for learning styles across different periods.

Future Research

Future research should further explore the intersection of learning styles, achievement, and affect—an area that remains both complex and underexamined. While our review considered how learning styles have been individually linked to achievement and affect, these two constructs are themselves often closely interconnected in educational research. Positive emotions and attitudes toward a subject can enhance motivation, engagement, and persistence, all of which may support academic performance. However, the assumption that improved affect automatically leads to better achievement outcomes remains contested and deserves further empirical attention (e.g., Lau & Ho, 2020). Given that several studies in our corpus addressed all three dimensions (e.g., Geiser, 1999; Santos et al., 2022), a deeper investigation of their interrelationships is warranted.

Future studies should critically evaluate claims that enhancing affective responses, such as increasing enjoyment, reducing anxiety, or boosting motivation, directly leads to academic improvement. This assumption is especially salient in mathematics education, where negative emotions and disengagement are common. In many cases, authors evaluated students' learning styles, achievement, and affect, likely because positive emotions and attitudes in mathematics may lead to better academic performance (e.g., Dan'inna, 2017). Research examining whether targeted affective interventions can yield measurable learning gains would help clarify the nuanced connections between emotion, engagement, and performance.

Additionally, future research could incorporate citation tracking to gain insights into the intellectual trajectory of learning styles research. Analyzing how foundational studies have been cited, whether to support, critique, or reinterpret their conclusions, can illuminate shifts in scholarly discourse and help explain the continued popularity of learning styles despite widespread empirical criticism. Future research should consider how different methodological approaches, such as longitudinal studies or mixed-methods designs, might yield a more comprehensive understanding of learning styles in practice. A more rigorous approach to studying learning styles, achievement, and affect, including experimental designs and validated instruments, could help establish clearer connections (or lack thereof) among these constructs.

Conclusion

Despite ongoing critiques and a lack of compelling evidence supporting the integration of learning styles into mathematics instruction, the neuromyth persists. While research communities in some regions appear to be moving away from the concept, scholars in other parts of the world have shown increased engagement with it. Consistent with prior research, we found that studies on learning styles remain methodologically inconsistent and often flawed. Authors frequently treat different learning style models as interchangeable, overlooking or conflating key distinctions between them. Similarly, the sheer number of instruments and the inconsistent use of terminology further contribute to confusion and the perpetuation of this concept. Although some suggest that encouraging educators to engage with current research might counter these trends, our findings indicate that researchers

continue to publish work supporting learning styles, often without sustained engagement with critiques of methodological rigor. Compounding this issue, most educators lack formal training in evaluating the quality of educational research, making it challenging to discern credible evidence from popular myths. While we cannot dictate what scholars choose to investigate, we can, and should, track these patterns and raise concerns when necessary. Consistent with Kirschner (2017) and Weale (2017), we urge teacher educators to prioritize instructional methods grounded in robust, consistent evidence and to equip future teachers with the tools to critically assess claims encountered in both research and practice.

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Appendix A: Extracted data

Citation	Study Location	Study Parameters (Achievement, Affect, or Learning Styles)			Achievement/ Affect, Instrument (Author, Outside Author, Grade, Classwork, Unstated)		Specific Learning Style(s) Mentioned (Visual, Auditory/Aural, Read/write, Kinesthetic, Other, None)						Learning Style Developer(s) Mentioned* (Dunn & Dunn, Kolb, McCarthy, Felder & Silverman, Fleming & Mills, Other, None)						Depth of Theory	
		Ac.	Af.	LS	Ac.	Af.	V	A	R	K	O	N	D&D	K	M	F&S	F&M	O		N
Angraini et al. (2023)	Asia	X			A							X							X	Minor
Ardianik et al. (2020)	Asia	X		X	A		X	X		X									X	Major
Arnup et al. (2013)	Australia	X			O		X					X						X		Minor
Aydin (2016)	Turkey		X	X		O	X	X					X	X	X					Major
Baltaci et al. (2016)	Turkey	X		X	G		X	X		X			X	X	X	X		X		Major
Birrell et al. (1985)	Europe	X		X	O							X						X		Major
Boaler (1998)	Europe	X			O							X							X	Moderate
Bosman & Schulze (2018)	Africa	X		X	G		X	X	X	X	X		X	X			X	X		Major
Capinding (2021)	Asia	X	X	X	G	O	X	X	X	X			X							Major
Copenhaver (1979)	North America		X	X		O						X						X		Major
Danişman & Erginer (2017)	Turkey	X		X	A		X	X	X	X						X	X	X		Major
Dwyer et al. (2009)	North America	X			A							X							X	Minor
Eissa & Mostafa (2013)	Did not specify	X	X		C	O	X			X	X		X							Major
Emihovich & Miller (1988)	North America	X	X		O	O	X	X					X					X		Moderate
Flexer (1987)	North America	X			A							X						X		Minor
Geiser (1999)	North America	X	X	X	A	O	X	X		X			X					X		Major
Gülten & Özkan (2013)	Turkey		X	X		A	X	X		X	X		X					X		Major
Hadfield et al. (1992)	North America	X	X	X	O	O	X	X					X					X		Moderate
Hannafin & Scott (1998)	North America	X			A; O							X							X	Minor
Hauptman & Cohen (2011)	Did not specify	X		X	O		X	X	X	X			X	X			X			Major
Hopkins (1999)	North America	X			A							X						X		Minor
Hussain et al. (2006)	Europe	X	X		O	A						X							X	Minor
Ikhsan, et al. (2020)	Asia	X			A		X		X										X	Minor
Kyriakides (2005)	Cyprus	X	X		A	A						X	X	X				X		Minor

Lindh & Holgersson (2007)	Europe	X			A						X						X	Minor
Lord & Clausen-May (2003)	Europe	X			O						X							Minor
Ma & Ma (2014)	Did not specify	X		X	O		X	X	X	X							X	Major
Mann (2014)	North America	X		X	O		X										X	Major
Niranjan & Brijlall (2024)	Africa	X			C		X	X		X			X					Major
Ozerem & Akkoyunlu (2015)	Did not specify	X		X	A		X	X	X			X			X			Major
Özyurt et al. (2012)	Turkey		X	X		A	X	X	X	X		X	X		X		X	Major
Özyurt et al. (2013)	Turkey		X	X		A	X	X		X		X	X		X		X	Major
Özyurt et al. (2014)	Turkey	X	X	X	A	A	X	X		X		X	X		X		X	Major
Rahman et al. (2016)	Asia	X		X	A		X	X		X		X						Major
Rahman & Ahmar. (2017)	Asia	X		X	U		X	X		X							X	Moderate
Santos et al. (2022)	Asia	X	X	X	O	A	X	X		X							X	Major
Sayed et al. (2023)	Did not specify	X		X	A		X	X	X	X							X	Major
Shahrill et al. (2013)	Asia	X		X	G		X		X	X							X	Major
Shirvani (2016)	North America	X		X	G		X	X		X		X	X			X		Major
Sriphai et al. (2011)	Asia	X	X	X	A	A	X	X	X	X	X	X	X		X	X		Major
Sulisawati et al. (2019)	Asia			X	A		X	X		X		X					X	Major
Suryawan et al. (2023)	Asia						X	X		X							X	Major
Tatar & Dikici (2009)	Turkey	X	X		A	O	X	X				X		X				Moderate
Ting & Tarmizi (2016)	Asia	X	X	X	G	A					X	X					X	Moderate
Tran et al. (2019)	Asia	X			A; O						X						X	Minor
Tully et al. (2006)	North America	X	X	X	A	O	X			X		X						Major
Virgana (2019)	Asia	X		X	U		X	X		X							X	Major
Wan Hussin & Mohd Matore (2023)	Asia		X	X		O**	X	X		X							X	Major
Weinhandl et al. (2022)	Europe		X			A					X						X	Minor
Yilmaz et al. (2016)	Turkey	X		X	O		X	X	X	X		X	X	X			X	Major
Zentall & Smith (1992)	North America	X		X	O		X	X		X	X	X					X	Moderate

*Note: Authors may have referenced a different work from the associated developer. For specific references, see the original article.

**This instrument was created by an outside author but adapted by the author

Appendix B: Codebook

Depth of Theory

(as described on the data extraction form)

Minor - Theory dropping or theory positioning: A discussion of theory is dropped after literature review and not revisited later; theory is introduced either at the beginning or end of a study without citation.

Moderate - Theory mapping: Feedback contributes significantly/explicitly to the design of the study/educational intervention, but not data analysis.

Major - Theory application, theory testing, or theory generation: Employs theory throughout to inform the research design and data analysis; Empirically validating an existing theory; Building, revising, or expanding a theory to create a new theory.

Linking Parameters

Conclusion	Definition	Example
Positive	Researcher(s) concluded that there was a positive link between learning styles theory and affect or achievement	“These findings support the conclusion that learning-style-responsive study/homework strategies offer a significant positive influence on students’ mathematics achievement...” (Geiser, 1999, p. 32)
Neutral	Researcher(s) concluded that there was no significant link between learning styles theory and affect or achievement	“However, no statistically significant relationship was found between the learning styles and the academic achievements of the EG students...” (Ozyurt et al., 2014, p.1)
Negative	Researcher(s) concluded that there was a negative link between learning styles theory and affect or achievement	None found

List of terms used and interpreted as achievement or affect

Achievement

- achievement
- ability to solve mathematical and logical problems
- attainment
- cognitive learning
- creative thinking
- critical thinking ability
- fluency
- grades
- knowledge
- learning
- learning achievement
- learning effectiveness
- learning outcomes
- mathematical reasoning and spatial ability
- math ability
- math scores
- mathematical communication skills
- mathematical computational thinking skills
- number sense competency
- perceptual reasoning strengths
- performance
- scores
- spatial strengths
- success
- understanding

Affect

- anxiety
- attitude
- beliefs
- motivation
- opinion
- procrastination
- self-concept
- self-efficacy
- self-esteem
- self-perception