Journal of
Numerical Cognition

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A Systematic Review of Secondary Students' Attitudes Towards Mathematics and its Relations With Mathematics Achievement

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Journal of Numerical Cognition, 2022, Vol. 8(2), 295–325, https://doi.org/10.5964/jnc.7937

Received: 2021-12-08 • **Accepted:** 2022-06-22 • **Published (VoR):** 2022-07-28

Handling Editor: Michele Mazzocco, University of Minnesota, Minneapolis, MN, USA

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Abstract

For a significant number of students, attitudes towards mathematics decrease notably during secondary education. Thus, there is an urgent need to improve students' mathematics attitudes because attitudes may negatively affect conceptual understanding of mathematics or mathematics performance. However, without a clear unified construct of mathematics attitudes, the ambiguity surrounding this construct prevents researchers from drawing broad conclusions about how to improve students' overall mathematics attitudes. Therefore, we conducted a systematic review of 95 studies focused on mathematics attitudes to clarify the construct and measurement of mathematics attitudes, and to provide a holistic picture of the relations between mathematics attitudes and math achievement. The review suggested the adoption of a multidimensional definition that regards mathematics attitudes as a combination of specific mathematical cognitions (value, gender roles/beliefs, confidence, self-concept), affects (enjoyment, anxiety), and behavioural intentions (i.e., willingness and tendency to spend more time learning mathematics subjects). The review then explored the relations between each subdimension of attitudes and mathematics performance. In general, anxiety and gender roles were negatively correlated with mathematics performance (r = -.27 to -.48; -.21) whereas enjoyment, self-concept, confidence, perceived value, and behavioural intentions were positively related to achievement (r = .27 to .68; .21 to .76; .34 to .42; .11 to .30; .21 to .34, respectively). Thus, mathematics attitudes appear to comprise three components with several subdimensions that each uniquely contribute to mathematics achievement. Going forward, researchers of mathematics attitudes should a) specify the components of mathematics attitudes used to guide their investigation b) adopt measures in line with their chosen components, and c) investigate how each subdimension of mathematics attitudes uniquely and cumulatively contribute to mathematics ability.

Keywords

mathematics attitudes, attitudes towards mathematics, mathematics achievement, control-value theory

Mathematics attitudes have long been studied in mathematics education, as 'attitude' is considered important for mathematics achievement (Neale, 1969). Critically, numerous studies report a significant decrease in students' mathematics attitudes, and the phenomenon is particularly visible among secondary students (secondary students are defined based on US grading system and refer to students from Grades 7 to 12, ages 12 to 18 in this paper) (Aiken, 1985; Fredricks & Eccles, 2002; Jacobs et al., 2002). For example, in an international mathematics test of 15-year-old students, less than one-third of students across all countries expressed positive attitudes towards mathematics (The Organisation for Economic Co-operation and Development [OECD], 2003). In fact, students in countries like Canada, Australia, and United Kingdom score below average on tests of interest and enjoyment in mathematics. Surprisingly, students with high mathematics achievement in countries like Finland and Japan also show negative mathematics attitudes (OECD, 2003). This is aligned with Fennema and Sherman (1976)'s claim that even students who are successful at mathematics may choose to avoid learning it.

Poor mathematics attitudes matter because they may reflect students' prior experiences with mathematics (Ma & Kishor, 1997), may affect students' conceptual understanding of mathematics (Markovits & Forgasz, 2017), and may even negatively impact mathematics performance (Ashcraft & Kirk, 2001; Hembree, 1990; Ma & Kishor, 1997; Passolunghi et al., 2016; Smetackova, 2015; Woodard, 2004). Low mathematics performance may further lead to avoidance of mathematics-related learning, higher drop-out rate from mathematics courses, and may eventually lead to job placement with lower incomes (Joensen & Nielsen, 2009; Rose & Betts, 2004). As such, mathematics attitudes are vital in achieving high performance and maintaining continued interests (Eccles et al., 1985; Haladyna et al., 1983; Lester et al., 1989). Clearly mathematics attitudes are important, so there is an urgent need to find an effective way to improve secondary students' mathematics attitudes before they decrease irrevocably. However, researchers define mathematics attitudes inconsistently, making it difficult to draw wide-reaching conclusions.

Mathematics Attitudes: A Disjointed and Unclear Construct

Despite an existing body of research on the connections between mathematics attitudes and mathematics ability, dimensions of 'mathematics attitudes' may need to be better organized under a theoretical framework. Currently, the dimensions of mathematics attitudes being explored include confidence (Ganley & Vasilyeva, 2011), gender beliefs (also known as gender roles or gender stereotypes), which include beliefs that male students are more capable to learn mathematics compared to female students (Spencer et al., 1999), anxiety (Hauge, 1991), enjoyment (Ma, 1997), and actions associated with either seeking or avoiding learning mathematics (Simsek, 2016). However, solely focusing on an individual dimension of mathematics attitudes may prevent researchers from drawing overarching conclusions about mathematics attitudes and their connections to mathematics performance.

Researchers may benefit from a strong theoretical framework that more coherently defines mathematics attitudes as a construct and identifies its unique dimensions. The current lack of a theoretical framework is demonstrated by the explicit but idiosyncratic definitions used across studies, none of which are widely adopted (Di Martino & Zan, 2010), the many researchers who avoid clearly defining the term in their research (Hart, 1989), and others that implicitly define the construct via their measurements (Leder, 1985; Daskalogianni & Simpson, 2000). For example, some researchers define mathematics attitudes as mainly affective feelings, such as "individual's like or dislike toward mathematics" (Mohr-Schroeder et al., 2017, p. 215). Some researchers argue attitude is the combination of affective feelings and cognitive beliefs, such as "a person's disposition towards a subject, beliefs a person held about that subject" (Mirza & Hussain, 2018, p. 12). Besides affective feelings and cognitive beliefs, some researchers include behavioural intentions (i.e., the willingness to spend more time in mathematics learning) when defining mathematics attitude, and describe it as "a liking or disliking of mathematics, a tendency to engage in or avoid mathematical activities, a belief that one is good or bad at mathematics, and a belief that mathematics is useful or useless" (Sengül & Dereli, 2013, p. 2527). These definitions each consider mathematics attitudes as comprised of different dimensions. As a result, the specific dimension and construct researchers adopt remains disjointed and unclear. Therefore, a single theoretical framework may facilitate more consistent categorization of the many dimensions of mathematics attitudes, which will in turn support researchers' efforts to study relations among those dimensions.

Mathematics Attitudes and Mathematics Achievement

Positive mathematics attitudes may improve mathematics achievement (Ma & Kishor, 1997; Ma & Xu, 2004). However, due to the lack of a theoretical framework and construct for mathematics attitudes, the exact relations between mathematics attitudes and mathematics achievement are ambiguous (Ma & Kishor, 1997). In Ma and Kishor (1997)'s meta-analysis of 113 studies, evidence of a causal relation between mathematics attitudes and math achievement seem too weak to reach statistical and clinical significance, which the authors attribute to the divergent definitions and measurement practices in the field (Ma & Kishor, 1997). Since Ma and Kishor's work, no study has systematically synthesized the definitions in use, categorized the various measurement practices, and analyzed the specific relations between each dimension of mathematics attitudes and mathematics achievement. Consequently, the definitions and measurements of mathematics attitudes in empirical work have continued down multiple divergent paths, and the relations between mathematics attitudes and mathematics achievement remain unclear.

Theoretical Frameworks for the Construct of Mathematics Attitudes

Zan and Di Martino (2007) suggest that the explicit definitions of mathematics attitudes used in research can be grouped into three categories: simple unidimensional definitions (affect focus), bi-dimensional definitions (affective and cognitive), and multidimensional definitions (affective, cognitive, behavioural). The use of multidimensional definitions by researchers suggests that a tripartite model could serve as the theoretical framework for mathematics attitudes. The tripartite model was originally used in the field of social psychology (Eagly & Chaiken, 1998), gradually gained a foothold in attitude theory (Breckler, 1984), and was later adopted in mathematics education (Leder, 1992; Ruffell et al., 1998). The tripartite model regards attitude as a complex construct with affective, cognitive, and behavioural components. It reflects not only the feelings associated with the object, but also the knowledge, ideas and beliefs about the object, and behavioural intentions towards the object. These three components are distinguishable as they each have their own antecedent: affects are the products of emotional stimuli, cognitions are products of previous exposure, and behavioural intentions are products of past reinforcement (Triandis, 1971). Though the three components of attitudes are unique, they may each influence actions (Breckler, 1984). Therefore, the tripartite model suggests that all three components (affective, cognitive, and behavioural) of mathematics attitudes may affect learning outcomes. The question at hand is whether the subdimensions of mathematics attitudes studied in the extant research align with the three components, as suggested by the tripartite model.

Control-Value Theory: A Theoretical Framework for the Relations Among Mathematics Attitudes and Achievement

One of the goals of improving mathematics attitudes is to promote academic achievement, thus the relations between the two phenomena has long been proposed and studied (Ethington & Wolfle, 1984, 1986; Lester et al., 1989; Ma & Xu, 2004; Nicolaidou & Philippou, 2003; Sherman, 1982; Suydam & Weaver, 1975). However, the existing research has not consistently found strong relations among mathematics attitudes and mathematics achievement: some researchers have claimed there is no causal relation between the two constructs (Quinn & Jadav, 1987), some suggest the correlation is weak (Aiken, 1970, 1976; Ma & Kishor, 1997), while others indicate a relatively strong correlation (Eldersveld, 1983; Kloosterman, 1991; Ma & Xu, 2004; Minato, 1983; Nicolaidou & Philippou, 2003; Yenilmez & Duman, 2008). Given the divergent definitions and measurement practices identified in this review, the inconsistent evidence could be due to researchers' use of disparate instruments (Ma & Kishor, 1997). Further, if mathematics attitude is a multidimensional construct then the relations among mathematics attitudes and mathematics achievement might not be a simple linear causal connection. Pekrun's control-value theory is well-suited for understanding how the three components of mathematics attitudes influence each other, and further affect learning outcomes.

Appraisals to Achievement Emotions

According to control-value theory, there are two types of appraisals that may affect achievement emotions (i.e., emotions closely related to achievement) and they are organized temporally, as proximal or distal (Pekrun & Perry, 2014). For proximal, two sub-types of appraisals are critical for the arousal of achievement emotions: control-related appraisals and value-related appraisals (Pekrun & Perry, 2014). Control-related appraisals are appraisals of one's controllability over achievement activities and outcomes. They consist of expectancies (confidence in one's ability to perform the action and achieve the goal successfully), causal attributions, and self-concepts of ability in the subject (e.g., "I'm good at mathematics"). Value-related appraisals describe the importance one places on mathematics activities and outcomes, either intrinsically or extrinsically (Pekrun & Perry, 2014). For example, an intrinsic value for mathematics can arise from the interests and fun during the learning process while an extrinsic value can arise from the benefits that being good at mathematics will produce (e.g., a better career and life). Achievement emotions are products of perceived value and control, with high value and control may lead to enjoyment while high value but low control may result in anxiety (Pekrun, 2006). Distal appraisals, such as achievement goals and gender roles, can also impact achievement emotions by influencing control-value appraisals (Pekrun, 2006). For example, girls with stereotypical gender beliefs/roles may have lower confidence and may evaluate themselves as possessing a low ability in learning mathematics compared to boys; this may generate achievement emotions such as anxiety.

Achievement Emotions to Behaviours

Control-value theory argues that the effects of achievement emotions on students' performance may be mediated by factors such as motivational behaviours (Pekrun, 2006). Positive achievement emotions (e.g., enjoyment) may reinforce the learning behaviour's, leading to reengagement in the learning activity, and result in better performance. In contrast, negative achievement emotions (e.g., anxiety) may undermine motivation and lead to avoidance of the learning task, which may further affect achievement (Pekrun, 2006).

To sum up, control-value theory can be used as a theoretical framework to predict the relations among the components of mathematics attitudes and mathematics achievement. From a control-value lens, mathematics attitudes are likely to affect achievement via the cognitive components influencing the affective components, which in turn may trigger different behaviours that lead to changes in mathematics achievement (Pekrun, 2006; Pekrun & Perry, 2014; Pekrun et al., 2007). Within the parlance of the theory, the cognitive and affective components of mathematics attitudes are referred to as appraisals and achievement emotions, respectively. Given this lens, this paper aims to explore the complex relations among mathematics attitudes and mathematics performance revealed in the current literature, and to evaluate whether they align with control-value theory.

Research Questions

Two questions guided a two-phased systematic review: for secondary students, (a) what are the components of mathematics attitudes that predominate the research literature and (b) what is the relation between each component and mathematics achievement? The present review focuses on secondary education because many students start to develop negative mathematics attitudes during the last two years of elementary education (Haciomeroglu, 2017) and these negative attitudes became particularly visible during secondary education (Aiken, 1985; Pajares & Miller, 1994). Further, mathematics attitudes in this article refer to feelings, beliefs, and intentions that are closely related to mathematics achievement (e.g., classroom and test performance); as such, studies of adults were excluded as their attitudes are not test-specific (e.g., attitudes towards daily usage of numbers, such as figuring out sales tax). Studies focusing on college and university students were also excluded because attitudes towards college or university level mathematics subjects, such as statistics and calculus, differ from attitudes about secondary mathematics (Hedges & Harkness, 2017). Secondary students who hold positive mathematics attitudes may not transfer those attitudes towards statistics, possibly due to statistics involving different reasoning and relying heavily on language (Carmona et al., 2005, as cited in Hedges & Harkness, 2017). Therefore, it is critical to identify the components of secondary students' mathematics attitudes so that researchers and educators may purposefully investigate which subdimensions of mathematics attitudes undergo an important negative shift at this stage.

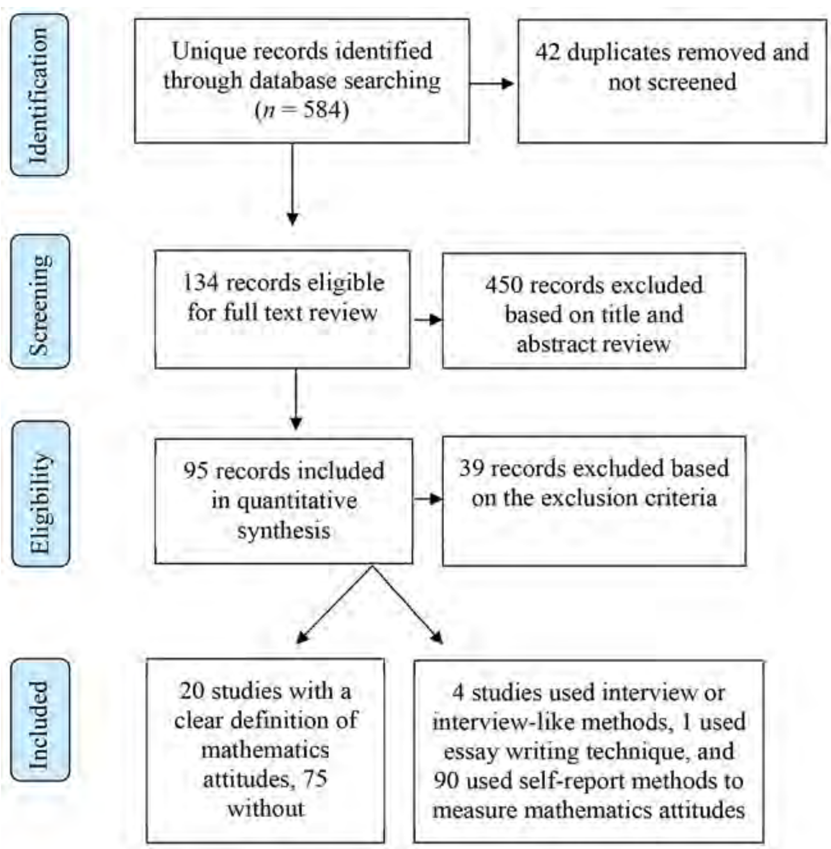
Phase 1. Components of Mathematics Attitudes

To answer question (a), 'math*' AND 'attitude* OR view* OR disposition* OR perspective* OR perception* OR perceive*OR think* OR opinion*' were searched in three databases (PsycINFO, ERIC EBSCO, Scopus), limited to English peer-reviewed articles. Based on these preliminary criteria, the initial search returned 626 articles. After removing duplicates, 584 articles were left for further review. Subsequently, a screening process was conducted. After reviewing titles and abstracts, 134 records were eligible for further review. Articles that did not just mention attitudes, but specifically examined them as part of the empirical work in secondary education (grades 7 to 12), were included for further analysis. If grades were not reported, ages (12 to 18) were used as inclusion criteria. Studies that overlapped with targeted grades or ages (e.g., grade 6-8 or ages 10-15) were also included. Several exclusion criteria were applied: dissertation/conference proceedings; annotated bibliographies; special education; teacher's/parents' attitudes towards mathematics; a focus solely on non-targeted students (such as elementary students, university students, and adults).

After a full-text analysis of these 134 studies, 95 studies meeting the criteria were included in the review (see Figure 1). The 95 studies included were then organized according to the following codes: 1) author(s), 2) year of publication, 3) definition of mathematics attitudes, 4) techniques used to measure mathematics attitudes, 5) aspects of mathematics attitudes being measured, 6) reported validity and reliability of the instruments.

Figure 1

Systematic Review Flow Diagram



Definitions

Among 95 articles, only 20 clearly stated their definition of mathematics attitudes, while the remaining articles did not define the term at all. Di Martino and Zan (2010) suggested that definitions of mathematics attitudes can be categorized into one of three types: unidimensional definitions reflecting emotional dispositions (affective components), bi-dimensional definitions (affective and cognitive components, e. g., emotions[1] and beliefs), or multidimensional definitions (affective, cognitive, and behavioural components, e. g., emotions, beliefs, and behaviours). However, there has been no review to examine if these three types of definitions are adopted within and across studies of mathematics attitudes. Thus, a three-type definition framework was adopted to guide the organization of studies. Findings revealed that most of the studies could be classified into Zan and Di Martino's three categories, except one study from the bidimensional category that defined attitudes from affective and behavioural perspective (see Table 1).

1) All references to emotions in this review are trait emotions (or habitual emotions) rather than state (or transitory) emotions.

Table 1

Mathematics Attitudes Definitions

n	Types of Definition	Aspects of Attitudes	Examples of Definitions	Citation
7	Unidimensional definition	Affective components	"the emotional tendencies developed by individuals"	(Eskici et al., 2017, p. 64)
			"a general emotional disposition toward the school subject"	(Haladyna et al., 1983, p. 20)
			"a positive or negative response towards mathematics that is relatively stable, similar to what some might call dispositions"	(Hemmings et al., 2011, p. 692)
			"one's general feeling of favor or otherwise toward some stimulus objects"	(Mallam, 1993, p. 223)
			"someone's basic liking or disliking of a familiar target"	(Mavridis et al., 2017, p. 1452)
			"individual's like or dislike toward mathematics"	(Mohr-Schroeder et al., 2017, p. 215)
			"predisposition to respond favourably or unfavourably to mathematics"	(Murimo, 2013, p. 75)
6	Bi-dimensional definition	Affective & cognitive components	"the sum total of a man's inclinations, feelings, prejudice or bias, preconceived notions, ideas, fears, threats and conviction about any topic"	(Ifamuyiwa & Akinsola, 2008, p. 570)
			"an aggregated measure of mathematics self-confidence, perceived usefulness, and enjoyment of mathematics"	(Kiwanuka et al., 2017, p. 3)
			"either positive or negative responses, in terms of importance, difficulty, and enjoyment"	(Ma, 1997, p. 222)
			"a person's disposition towards a subject, beliefs a person held about that subject"	(Mirza & Hussain, 2018, p. 12)
			"the result of highly interdependent aspects of beliefs and emotions"	(Moyer et al., 2018, p. 117)
		Affective & behavioural components	"emotional disposition towards mathematics, such as a positive or negative response towards mathematics, or a liking or disliking of mathematics, or a tendency to engage or avoid mathematical activities"	(Yang, 2015, p. 252)
7	Multidimensional definition	Affective, cognitive & behavioural components	"A persons' attitude to an idea or object determines what the person thinks, feels and how the person would like to behave towards that idea or objects"	(Etuk et al., 2013, p. 197)
			"emotional reaction to an object, behavior tendency towards an object and beliefs about the object"	(Idil et al., 2016, p. 210)
			"a mental, emotional and behavioural reactionary predisposition a person develops toward mathematics".	(Koyuncu & Dönmez, 2018, p. 1631)
			"an aggregated measure of a liking or disliking of mathematics, a tendency to engage in or avoid mathematical activities, a belief that one is good or bad at mathematics, and a belief that mathematics is useful or useless"	(Mutohir et al., 2018, p. 1)
			"attitudes consist of cognitive, affective and behavioural reactions that individuals display towards an object or the surrounding based on their feelings or interest"	(Sanchal & Sharma, 2017, p. 89)
			"a liking or disliking of mathematics, a tendency to engage in or avoid mathematical activities, a belief that one is good or bad at mathematics, and a belief that mathematics is useful or useless"	(Sengül & Dereli, 2013, p. 2527)
			"a tendency attributed to the individual and regularly constitutes his/her thoughts, feelings and behaviours related to the psychological incident"	(Zakariya, 2017, p. 75)

Unidimensional Definition

Seven articles used unidimensional definitions, all of which referred to emotional dispositions towards mathematics. Two of these studies defined mathematics attitudes as "general emotional disposition toward the school subject" (Eskici et al., 2017, p. 64; Haladyna et al., 1983, p. 20). Five made more specific reference to either liking or disliking mathematics. For example, Mallam (1993, p. 223) defined mathematics attitudes as "one's general feeling of favor or otherwise toward some stimulus objects". Two studies from this category used measures that seemed to contradict the definitions they adopted. Specifically, Mavridis et al. (2017, p. 1452), defined mathematics attitudes as "someone's basic liking or disliking of a familiar target" which these researchers' measured with survey items not only tapping affective components (e.g., "I have really enjoyed studying mathematics in school"), but also involving value (e.g., "Mathematics is important in everyday life") and behavioural intensions (e.g., "I am willing to take more than the required amount of mathematics"). Likewise, Murimo (2013) measured students' perceived value and usefulness of mathematics together with affective components. The disconnect between measures and definitions of mathematics attitudes implicitly suggests there may be a better way to define the term rather than focusing solely on one dimension.

Bi-Dimensional Definition

Six articles used bi-dimensional definitions, all acknowledging the importance of affects. Five articles suggested that mathematics attitudes are the combination of affects and beliefs towards the subject (Ifamuyiwa & Akinsola, 2008; Kiwanuka et al., 2017; Ma, 1997; Mirza & Hussain, 2018; Moyer et al., 2018). For example, Moyer et al. (2018, p. 117) defined it as “the result of highly interdependent aspects of beliefs and emotions”. Similarly, Mirza and Hussain (2018, p. 12) defined attitudes as “a person’s disposition towards a subject, beliefs a person held about that subject”. Two other studies identified components of mathematics attitudes via their measures. Kiwanuka et al. (2017, p. 3) suggested measuring “mathematics self-confidence, perceived usefulness, and enjoyment of mathematics” while Ma (1997, p. 222) proposed “importance, difficulty, and enjoyment”. Both suggested measuring enjoyment in terms of the affective components but hold different opinions on cognitive components. Another study defined the term as including affective and behavioural aspects (Yang, 2015, p. 252), suggesting that attitude is an “emotional disposition towards mathematics, such as a positive or negative response towards mathematics, or a liking or disliking of mathematics, or a tendency to engage or avoid mathematical activities”. The same study suggested to mainly measure attitudes via “self-confidence, usefulness of mathematics, and motivation”. Studies that regard mathematics attitudes as two dimensions held divergent views on definitions and components of mathematics attitudes. Therefore, studies adopting bi-dimensional definition seemed to not agree with one another.

Multidimensional Definition

Seven articles used multidimensional definitions, which treated mathematics attitudes as consisting of three dimensions: cognitive (the knowledge of mathematics, ideas and beliefs towards mathematics), affective (feelings associate with mathematics) and behavioural (actions towards mathematics) (Etuk et al., 2013; Idil et al., 2016; Koyuncu & Dönmez, 2018; Mutohir et al., 2018; Sanchal & Sharma, 2017; Sengül & Dereli, 2013; Zakariya, 2017). For example, Idil et al. (2016, p. 210) proposed that a mathematics attitude is an “emotional reaction to an object, behavior tendency towards an object and beliefs about the object”. Koyuncu and Dönmez (2018, p. 1631) suggested mathematics attitude is “a mental, emotional and behavioural reactionary predisposition a person develops toward mathematics”.

Given that there are three approaches to define mathematics attitudes, one may wonder which approach is the most suitable for studying mathematics attitudes. Unlike the other two definitions, the multidimensional definition is supported by a theoretical framework—the tripartite model of attitudes (Di Martino & Zan, 2003). Moreover, with the support of the tripartite model, the multidimensional definition may help resolve the confusion caused by different measures of mathematics attitudes being used in the field. For example, McLeod (1992) argued that the confusion/inconsistency is caused by a lack of guiding theoretical framework. Finally, the multi-dimensional definition contains all aspects of attitudes used in research and theory. Therefore, this paper will adopt a multidimensional definition of mathematics attitudes to reflect both theoretical viewpoints and practical uses.

Measurements

Having adopted the multidimensional definition, the next step is to identify how the specific components of affect, cognition, and behaviour are most commonly measured. Doing so will further clarify what each dimension of mathematics attitudes is actually being assessed. This was achieved through a systematic analysis of the mathematics attitudes measurement tools used in the identified 95 studies.

There are three commonly used techniques to measure mathematics attitudes (Corcoran & Gibb, 1961): observations, interviews, and self-report methods (e.g., questionnaires/scales). In this review, none of the studies used observations, four used interview or interview-like methods, one used essay writing techniques, and ninety used self-report methods (see Table 2). Observations made by teachers are suggested to be a good indicator of students’ attitudes (Bialangi et al., 2016), but previous literature showed mixed results. Ellingson’s study (1962) showed a positive correlation between teacher’s observation and students’ self-reported attitudes while Brown and Abell’s study (1965) suggested that observation was inadequate. This could be explained by individual differences, where teachers in different studies interpret behaviour differently. Interviews may overcome some of the limitations of observation by asking students’ feelings directly. Four studies used interview or interview-like methods (open ended questions) to get students talking about their mathematics attitudes (Hannula, 2002; Joffe & Foxman, 1984; Kaiser-Messmer, 1993; Moyer et al., 2018). These interviews covered the value of learning math, perceived difficulty, confidence, emotions, and time spent on mathematics. One potential limitation to this approach is that students may not feel comfortable expressing their negative feelings face-to-face. One study used an essay writing technique, where students were asked to write an essay on their attitudes towards mathematics (Di Martino & Zan, 2010). Common topics covered in the essays were emotional dispositions, vision of mathematics, and perceived competence of learning mathematics.

Table 2

Techniques Used for Measuring Mathematics Attitudes in 95 Reviewed Articles

Techniques	**Number of Studies**	
Observations	0	
Essay Writing	1	
Interviews	4	
Self-reported Methods (Scales)	90	
	Cited in 95 Studies Reviewed	Used in 95 Studies Reviewed
Fennema-Sherman Mathematics Attitudes Scales (FSMAS)	39	10
Aiken's Math Attitude Scale	31	4
Attitudes Toward Mathematics Inventory (ATMI)	10	6
The Mathematics Attitude Scale	5	3
Sandman's Mathematics Attitude Inventory (MAI)	5	2
Modified scales	1	34
Self-developed scales	NA	24
No specific measure described or identified	NA	7

For the 90 studies using self-reports, the specific instruments, latent variables, reliability, and citation were documented (see Table 3 and Appendix A). Though most of the studies in this review used self-reports, different instruments were applied. Interestingly, only 25 studies used well-known scales, including Fennema-Sherman Mathematics Attitudes Scale (Fennema & Sherman, 1978), Aiken's math attitude scale (Aiken, 1970), Attitudes Toward Mathematics Inventory (Tapia & Marsh, 2004), The Mathematics Attitude Scale (Aşkar, 1986), and Sandman's Mathematics Attitude Inventory (Sandman, 1980), among which, Fennema-Sherman Mathematics Attitudes Scale and Aiken's math attitude scale being the most cited (see Table 2). In contrast, 34 studies used scales modified from literature (including ones adapted from PISA and TIMSS's), 24 studies developed their own measures, and 7 studies did not clearly state which scales they used.

Table 3

Summary of the Instruments Used

Name	**Cognitive Components**	**Affective Components**	**Behavioural Components**	**Type of Scale**	**Used in Studies Reviewed**
FSMAS	Confidence (9)[b], Value (7), Gender roles (7), Attitude towards success (6), Perception of parents/teacher's attitudes (5)	Anxiety (3), Affect (3),		Bi-dimensional	10
ATMI	Confidence (5), Value (5)	Enjoyment (6), Motivation (5)		Bi-dimensional	6
Aiken's Math Attitude Scale	Value (4)	Enjoyment (4)		Bi-dimensional	4
The Mathematics Attitude Scale		Enjoyment (3)		Unidimensional	3

Name	Cognitive Components	Affective Components	Behavioural Components	Type of Scale	Used in Studies Reviewed
MAI	Perception of math teacher (2), Value (2), Self-concept in math (2)	Anxiety (2), Enjoyment (2), Motivation (2)		Bi-dimensional	2
Modified Scales	Value (18), Confidence (12), Gender roles (5), self-concept (5), attention (1), Perceived difficulty (1), Attitudes towards school (1), Learning (1), math teaching (1), Teacher's attitudes (1), Nature of math (1), Attitudes towards school (1)	Enjoyment (16), Anxiety (8), Motivation (2), Feelings (1)	Behavioural Intentions (4)	Multidimensional	34
Self-developed Scales	Value (13), Gender roles (8), Self-concept (8), Confidence (4), Perception of difficulty (3), Parents' perception (3), Teachers' impact (3), Perceived control (1), Rules (1), Intention (1), Home-support (1), Home-process (1), Society (1) Fatalism (1)	Enjoyment (13), Boredom (4), Anxiety (5), Feelings (1)	Behavioural Intentions (7), More attention (1)	Multidimensional	24
No specific measure described or identified					7

[a]The number of studies in the review that used a given scale as a measurement tool. [b]The number of studies in the review that adopted each component.

Fennema-Sherman Mathematics Attitudes Scales

Fennema-Sherman Mathematics Attitudes Scale (FSMAS) was one of the most popular scales in this review, with 39 articles out of 95 citing it and 10 studies applying it. FSMAS was initially designed to explore gender differences in mathematics learning and other factors that influence the selection of mathematics courses (Fennema & Sherman, 1978). FSMAS is a bi-dimensional scale. It contains nine subcategories, among which, seven are cognitive components, including students' confidence, gender roles (see math as a male domain subject), perceived value, attitudes toward success, and parents' and teacher's mathematics attitudes. The other two are affective components, such as anxiety and motivation. However, only two studies adopted the full FSMAS scale, while other studies only adopted part of the scale without providing details as to how and why certain components were chosen. As shown in Table 3, the most commonly used components in FSMAS were confidence, followed by value, gender roles, attitudes towards success, and perception of parent's/teacher's attitudes, with the percentage of 90%, 70%, 70%, 60%, and 50% respectively.

Attitudes Toward Mathematics Inventory

The Attitudes Toward Mathematics Inventory (ATMI) developed by Tapia and Marsh (2004) was another commonly adopted scale, with 10 articles citing it and 6 applying it (Tapia & Marsh, 2004). ATMI is a bi-dimensional scale, with confidence and value as cognitive components, and enjoyment and motivation as affective components. As shown in Table 3, six studies adopted ATMI or short versions of it. Confidence was adopted in all 6 studies, while the other three components in the scale (value, enjoyment, and motivation) were equally applied in 83% of the studies.

Aiken's Math Attitude Scale

Aiken's math attitude scale was cited by 31 studies in this review but only four used it to measure mathematics attitudes. Aiken's math attitude scale is a bi-dimensional scale, which only contains enjoyment as the affective component and value of mathematics as the cognitive component. In this review, all four studies that adopted Aiken's math attitude scale applied both enjoyment and value components.

The Mathematics Attitude Scale

The Mathematics Attitude Scale developed by Aşkar (1986) was cited by 5 but applied by 3 studies. Compared to others, this scale was not widely accepted, perhaps because it is unidimensional and solely assesses the affective aspects of attitudes. The affective aspect is measured through 20 items focused on students' enjoyment of learning mathematics. As such, this scale was limited to measuring enjoyment and this may explain its infrequent use.

Sandman's Mathematics Attitude Inventory

Sandman's mathematics attitude inventory (MAI) was cited by 5 studies and applied by 2. It is designed to measure students' mathematics attitudes from Grade 7 to Grade 12 (Sandman, 1980). MAI is a bi-dimensional scale, with perception of mathematics teachers, value of mathematics, and self-concept as cognitive components, and anxiety, enjoyment, and motivation as affective components. The two studies using the MAI did not adopt the full scale, with each study only using half of the six components covered by the measure. This selective use of mathematics attitude measures further reinforced the disconnect between researchers' theoretical approach and the tools used to study mathematics attitudes.

No Clear Statements Regarding Scales

Surprisingly, 7% of the studies in this review did not provide any information about the measures they used, but still reported an increase or decrease in student's mathematics attitudes. While it may be possible to contact the authors for more details and infer the theoretical approach by applying an item-by-item analyses of the measures, it is critical for researchers to specify the measures used in the study so that future work can meaningfully compare their results against other studies.

Modified Scales

Approximately 36% of studies adapted existing measures (n = 34), with the majority of the adapted measures only being used in a single study. The modified measures covered all three dimensions of mathematics attitudes (affective, cognitive, behavioural). The reliability varied from study to study as different measures were applied. After removing unreliable measures (α less than .7), the commonly used components of mathematics attitudes being indexed by these modified measures were identified (see Table 3). Among all the components, value, enjoyment, and confidence were most common, with each being cited in 53%, 47%, and 35% of the studies, respectively. The second most common components were anxiety, behavioural intentions, gender roles, and self-concept, applied in 24%, 24%, 15%, and 15% of the studies, respectively. The high number of modified scales and their diverse composition suggests that researchers may need a more comprehensive tool to reflect many dimensions of mathematics attitudes.

Self-Developed Scales

Approximately 25% of the studies used self-developed measures (n = 24). With the exception of three that did not identify the components indexed by their instruments, the other self-developed measures covered all three dimensions of mathematics attitudes (affective, cognitive and behavioural components). The Cronbach alpha for these measures ranged substantially, from .34 to .98. Given this, five studies' measures with a reliability coefficient less than .7 were not considered further. Among all the components covered by self-developed measures, value, gender roles, self-concept, and confidence were commonly used to represent cognitive aspects of attitudes, each were cited in 54%, 33%, 33%, and 17% of studies. Enjoyment, anxiety and boredom were commonly used to assess affective components of mathematics attitudes, each were cited 54%, 21%, and 17% of studies respectively. Finally, behavioural intentions were often used to represent behavioural components (29% of studies). Similar with modified scales, the high number of self-developed scales further suggests that the available measures of mathematics attitudes may not align with researchers' approach to the subject.

A Praxis Construct of Mathematics Attitudes—Tripartite Construct

In general, 58 measures identified in this review were either self-developed or adapted from literature. This lack of agreement may represent the numerous facets of "attitudes" that researchers deem worthy of study. Even for scales commonly cited in the literature (e.g., Fennema-Sherman Mathematics Attitudes Scale and Aiken's Mathematics Attitude Scale), even fewer studies actually used them; suggesting these scales may fail to represent researchers' view of mathematics attitudes. Thus, there is a need to clarify the facets of mathematics attitudes and identify the dominant components of attitudes found in the literature. Based on the frequency of components used in this systematic review (see Table 3 and Appendix A), a praxis derived construct of mathematics attitudes was generated to represent the understanding of mathematics attitudes as indicated by research practice (see Table 4).

Table 4

Praxis Construct of Mathematics Attitudes

Cognitive Components	Affective Components	Behavioural Components
Value (49)[a]	Enjoyment (44)	Behavioural intentions (11)
Confidence (30)	Anxiety (18)	
Gender roles (20)		
Self-concept (15)		

[a]The numbers in parentheses represent the number of citations in this review.

There are three aspects to mathematics attitudes in the tripartite construct of mathematics attitudes: cognitive, affective, and behavioural. For the cognitive aspect, value of mathematics, confidence in solving mathematical problems, gender role beliefs in learning mathematics, and self-concept of mathematics were the most cited components. Among the 90 studies that used self-reports in this systematic review, each cognitive component was reported in 54%, 33%, 22%, and 17% of the studies respectively. Importantly, confidence (or self-efficacy) and self-concept (sometimes called self-beliefs, self-evaluation) are very similar terms, with one measuring the degree to which students believe they can handle mathematics' difficulties and get good outcomes while the other measures one's perception of themselves with mathematics. One example item for confidence is "I can get good grades in mathematics" (Fennema & Sherman, 1978). An example item for self-concept is "I have always believed that mathematics is one of my best subjects" (Stankov et al., 2012). For the affective aspect, enjoyment and anxiety were the common components being cited, each affective component was reported in 49% and 20% of studies respectively. For the behavioural aspect, behavioural intentions was the only commonly cited component. It was reported in 12% of studies. As such, these specific components were adopted into our tripartite construct of mathematics attitudes and will be used in the subsequent analysis of the relations between mathematics attitudes and mathematics achievement.

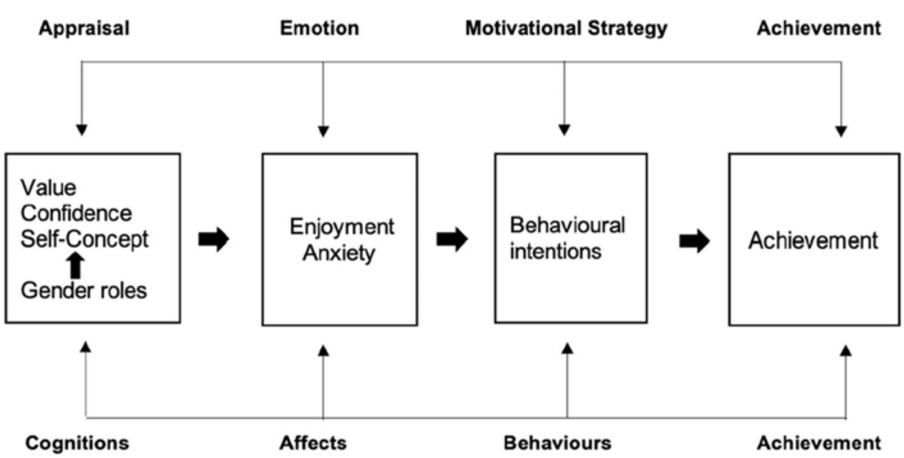
Other components such as perception of parents'/teachers' attitudes and motivation were also frequently used in different studies but were excluded due to the overlap with other components. Perception of parents' and teachers' attitudes was used in 14 studies out of 95. We agree with the importance of both parents' and teachers' attitudes in affecting students' mathematics attitudes and corresponding performance (Aiken, 1970). However, students' perception of parents' and teachers' attitudes are not appropriate in representing their own mathematics attitudes for two reasons. One, parents influence children's subject-specific attitudes in three ways: through support and encouragement, through expectation of children's performance, and through their own value beliefs of mathematics (Poffenberger & Norton, 1959). These three influences are reflected in students' self-concept, perception of gender roles in the subject, and value of mathematics, which are already present in the praxis construct of mathematics attitudes. Moreover, there may be differences between student's perception of parents'/teachers' attitudes and the actual attitudes held by parents/teachers. Therefore, students' perception of parents'/teachers' attitudes are not suitable to represent students' own attitudes due to overlap and lacking accuracy. Another commonly used component, motivation, was also excluded. Though 10% of the studies in this review considered motivation, others think that motivation can be expressed through other subdimensions of attitude (Chamberlin, 2010). For example, one may feel joy when they are highly motivated to learn math. Also, items used to measure motivation were mainly measuring student's desire to spend more time on math (e.g., "I would like to spend more time doing mathematics after class"), which overlap with the behavioural component. Therefore, motivation was removed due to overlapping with other included constructs.

Phase 2. Relations Between Mathematics Attitudes and Mathematics Achievement

Having clarified the subdimensions and constructs of mathematics attitudes in Phase 1, we will unpack the relations between mathematics achievement and each component of mathematics attitudes. Theoretically, the relations among components in mathematics attitudes and mathematics achievement can be organized based on control-value theory. For instance, cognitive components of mathematics attitudes such as value, confidence, self-concept, and gender roles line up with control-value theory' appraisal factors, while the behavioural component fits the motivational strategy (either seeking or avoiding the task). Affective components such as enjoyment and anxiety align with achievement emotions, and link cognitive and behavioural components as a whole (see Figure 2). This assumption was tested in the following literature review of the relations between mathematics performance and each component in mathematics attitudes.

Figure 2

Control-Value Theory Framework of How Mathematics Attitudes Relate to Mathematics Achievement



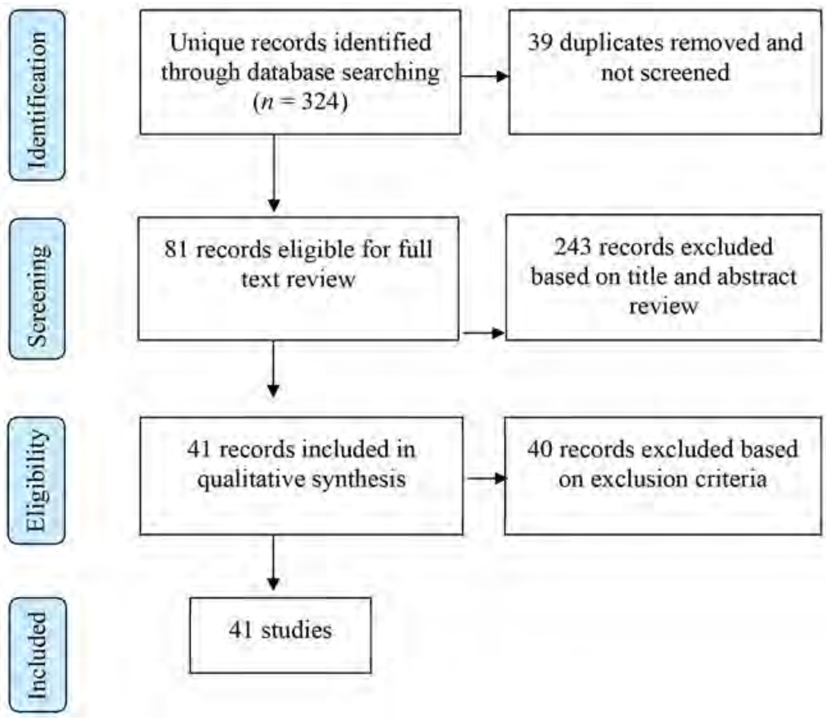
Note. Control-value theory serves as a framework to understand the relationship between mathematics attitudes and mathematics achievement. Adapted from "The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice," by R. Pekrun, 2006, *Educational psychology review, 18*(4), 315-341. Copyright 2006 by Springer.

Search Strategies

For the relations between each component in mathematics attitudes and mathematics performance, keywords were searched together (e.g., value*, gender* OR stereotype*, confidence*, self-concept*, enjoy*, anxi*, engag* AND "math* AND performance* OR achievement* OR grade* OR score* OR success"). Snowball sampling and forward citing techniques were also applied to add articles. The same exclusion criteria used in Phase 1 of the study was applied when reading abstracts. Finally, 41 research studies were identified and reviewed in total (see Figure 3). Among reviewed studies, 95% did not report socioeconomic status. In terms of country, except the review studies or the one that applied PISA data from different countries, 86% of them were conducted in North America (e.g., United States, Canada) and Europe (e.g., Germany, Greece, Portuguese, Netherlands), with 14% focused on Asian students (e.g., India, China, Singapore).

Figure 3

Systematic Review Flow Diagram

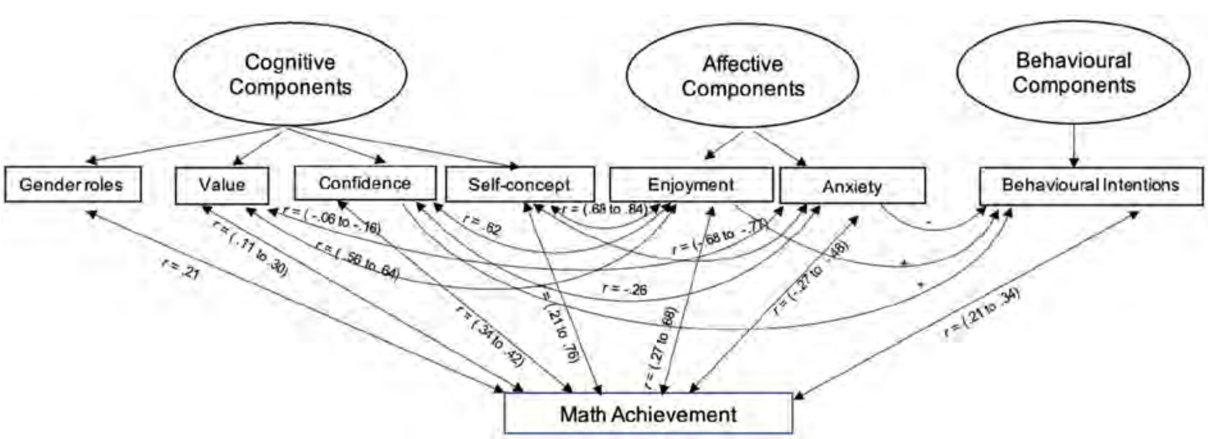


Relations Between Mathematics Attitudes and Mathematics Achievement

Based on the result of the review, Figure 4 illustrates the unique relations among each component of mathematics attitudes and mathematics achievement. In what follows, we briefly explain these results.

Figure 4

Relations Among Mathematics Attitudes and Mathematics Achievement



Note. This figure demonstrates the relations in the reviewed empirical studies. The ranges represent correlations from multiple studies while a single r is one estimation from one study.

Gender Roles/Beliefs/Stereotypes

Generally, having strong gender roles/beliefs/stereotypes makes students regard mathematics as a male dominated subject (Hyde et al., 1990). Gender role/belief is a product of cultural reinforcement and results in the view of boys being better skilled at mathematics than girls (Fennema et al., 1990). Historically, Aiken (1970) argued that this gender stereotype does not develop until the secondary school level. More recently, a study of 1300 adolescents asked students whether they see mathematics as a male domain, female domain, or gender-neutral domain subject. Most students viewed it as male domain subject, with this belief being particularly stronger amongst boys (Brandell & Staberg, 2008). This result is in line with Cai et al.'s (2016) finding, who argue that a lot of adolescents possess gender stereotypes in mathematics and science subjects.

Both control-value theory and empirical studies indicated that internalized gender roles may affect students' mathematics achievement (Li, 1999; Pekrun, 2006). For example, Fennema and Sherman (1978) examined 1233 students' gender stereotypes and the results showed that girls' gender roles/beliefs negatively correlated with their mathematics achievement (r = -.21). Control-value theory also implies that gender roles may affect students' achievements by influencing control-value appraisals (e.g., value, self-concept, confidence) and achievement emotions (Pekrun, 2006). For instance, female students who have stronger gender roles/beliefs tend to evaluate themselves as possessing a low capacity in learning mathematics compared to boys. This may generate more anxiety while doing mathematics and result in lower mathematics achievement. However, none of the studies reviewed examine the mediating effect of control-value appraisals and achievement emotions in secondary education. So, whether value, self-concept, confidence, and achievement emotions such as anxiety play a role in mediating the effects of gender roles/ beliefs on mathematics achievement remains unclear.

Value

Perceived value measures how much importance students place on mathematics. Control-value theory suggests that student's value appraisals affect their achievement emotions and further affect motivational behaviour and academic achievement (Pekrun, 2006). In line with this assumption, studies showed that value positively predicted enjoyment (r = .56 to .64) and negatively predicted anxiety (r = -.06 to -.16) (Luo et al., 2016; Peixoto et al., 2017). As for studies examining the direct relation between value and achievement, the results indicated a weak correlation. For example, Chouinard et al.'s (2007) analysis of 759 Grade 7 to Grade 11 students showed that perceived value had a significant but small relationship with mathematics performance (r =.29). In Hammouri's (2004) analysis of TIMSS data, students' perceived value of mathematics also related to mathematics performance (r = .11). Moreover, female students seemed to produce a stronger correlation between value and achievement than male students (r = .30/.26 respectively) (Lim & Chapman, 2015).

Confidence

Confidence in mathematics is the degree to which students believe they can handle mathematics' difficulties and get good outcomes. Based on control-value theory, confidence is supposed to affect achievement through influencing achievement emotions and motivation (Pekrun, 2006). In line with this assumption, research indicates a strong positive correlation between confidence and enjoyment (r = .62) and a negative correlation between confidence and math anxiety (r = -.26) (Luo et al., 2016). Moreover, confidence was also a good predictor of students' continuing participation in mathematics (Barkatsas et al., 2009). In fact, students with high levels of confidence spent more time learning mathematics (Barkatsas et al., 2009). The empirical studies that explore the direct relations between confidence and achievement suggested that confidence was an important predictor of mathematics performance (Lee, 2009; Marsh & Yeung, 1997). An analysis of PISA 2003 data indicated that confidence was a significant predictor of mathematics achievement for fifteen-year-old students (Liu & Wilson, 2009). Hammouri's (2004) analysis of TIMSS 2003 data also indicated that students' confidence was correlated with mathematics performance (r = .34). Similarly, Perry et al. (2016) tested 84 high school students and showed a moderately sized positive relation between confidence and algebra achievement (r = .42). In sum, both theory and empirical evidence suggest that confidence is a good predictor of emotions, behavioural intentions, and mathematics achievement. The high level of confidence may lead to positive achievement emotions, which may further result in more engagement in learning mathematics and better learning outcomes.

Self-Concept

Self-concept is one's perception of themselves in a certain environment (Shavelson et al., 1976). Mathematics self-concept is students' perception of themselves in mathematics. Based on control-value theory, self-concept's impact on mathematics achievement is mediated by achievement emotions and motivational behaviours (Pekrun, 2006). Control-value theory implies that appraisal has a reciprocal relation with emotions such that self-concept and emotions predict each other (Pekrun, 2006). In line with this assumption, empirical research has reported strong positive correlations between self-concept and enjoyment and negative correlations between self-concept and anxiety (Goetz et al., 2010; Jain & Dowson, 2009). Hembree's (1990) meta-analysis examined the relation between self-concept and anxiety and revealed a strong correlation (r = -.71). Ahmed and colleague's (2013) longitudinal design assessed self-concept and anxiety in three different time points across one academic year and revealed a consistent reciprocal relation in which self-concept's effect on anxiety was twice larger than anxiety's effect on self-concept. Goetz et al. (2010) systematically tested the relation between self-concept and five emotions (enjoyment, pride, anxiety, anger, and boredom), and the results also suggested strong correlations between self-concept and enjoyment/anxiety in mathematics (r = .68 to .84/ r = −.68 to −.77). Moreover, the relationship was stronger for higher grade levels in both cases (Goetz et al., 2010). Meanwhile, empirical studies that explore the direct relations between self-concept and mathematics achievement reported a consistent positive correlation (Lee, 2009) but strength differed from study to study. In a meta-analysis conducted by Hansford and Hattie (1982), self-concept was positively correlated with mathematics performance, but the relation was weak (r = .21 to .26). In contrast, a study of 1710 Grade 8 and 11 students found an increasing, strong correlation (r = .68/.76) (Goetz et al., 2010). This discordant strength could be explained by age and Grade level differences, as Rech (1994) suggested that the interaction of self-concept with achievement significantly changes across grades. In sum, both theory and empirical evidence suggest that self-concept in mathematics is significantly associate with enjoyment, anxiety, and achievement.

Enjoyment

Control-value theory implies that achievement emotions like enjoyment and anxiety are affected by students' gender and appraisals of their value, self-concept, and confidence (Pekrun, 2006). This assumption is supported with empirical studies discussed above, where value, confidence, and self-concept had a moderate relation with enjoyment (Goetz et al., 2008; Luo et al., 2016; Peixoto et al., 2017). Meanwhile, many studies exploring the direct relation between enjoyment and achievement indicate a moderate to strong positive interrelation (Van der Beek et al., 2017). For example, in a cross-cultural study of 891 Grade 8 students from Germany and China, enjoyment was positively correlated with mathematics achievement (r = .39 to .66) (Frenzel et al., 2007). Similarly, Ahmed et al. (2013) assessed 495 Grade 7 students' achievement and enjoyment three times in a year in a short-term longitudinal study and found that students' achievement systematically changed with their enjoyment. This same relationship was reported across many grade levels by Jerusalem and Mittag (1999) and Pekrun et al. (2017), with enjoyment in mathematics positively predicting mathematics achievement (r = .27/.43/.68 in Grade 7/10/12, respectively). Therefore, both theory and empirical results reveal a clear positive correlation between enjoyment and value, self-concept, confidence, as well as mathematics achievement.

Anxiety

Math anxiety is a negative feeling combined with fear and tension when dealing with mathematical problems (Richardson & Suinn, 1972). As with enjoyment, anxiety is influenced by students' gender and appraisal of their value, self-concept, and confidence (Pekrun, 2006). Empirical studies showed that girls who hold gender stereotype tend to be more anxious about mathematics (Casad et al., 2015). Also, a negative correlation between value, self-concept, confidence, and anxiety were reported as discussed above (Luo et al., 2016; Peixoto et al., 2017). Moreover, both theory and empirical evidence suggested that anxiety affects students' performance and achievement in mathematics (Ashcraft & Faust, 1994; Pekrun, 2006). For example, students with mathematics anxiety showed more difficulty in computing and were less likely to use new strategies compared to their peers (Ashcraft & Faust, 1994). Negative correlation between anxiety and mathematics achievement were reported in most of the reviewed studies (r = -.27 to -.48), with high math-anxious students tending to perform worse than those with low anxiety (Brassell et al., 1980; Hembree, 1990; Lee, 2009; Ma, 1999; Reese, 1961; Zakaria & Nordin, 2008), and the phenomenon has been observed in all grades (Ma, 1999).

Behavioural Intentions

Behavioural intentions measure students' action or potential behaviours towards mathematics. An example item is "I think about mathematics problems outside school and like to work them out" (Tocco, 1971). Control-value theory holds that students' emotions affect their motivational strategy (i.e., time spent on mathematic tasks), which further affects academic performance (Pekrun, 2006). Studies indicated that anxiety was negatively influencing students' behavioural intentions where students with mathematics anxiety tried to avoid math-related activates (Beilock & Maloney, 2015; Hembree, 1990). In contrast, students who reported higher enjoyment spent more time on mathematics (Tulis & Fulmer, 2013). Interestingly, control-value theory implies that confidence affects behavioural intentions via emotions whereas the reviewed empirical studies suggested confidence is a significant predictor of choosing more elective mathematics courses (Hackett & Betz, 1989). The direct contribution of confidence to behavioural intentions seems to overlook the mediated effect of emotions. However, control-value theory argues that emotions can become nonreflective and routinized over time such that appraisals and emotions are directly linked (Pekrun, 2006). Therefore, confidence can be directly linked to a certain level of enjoyment and anxiety, which may further influence behavioural intentions in a more direct way. Finally, a reciprocal relation was also reported between behavioural intentions and mathematics achievement (r = .21 to .34), where students with high performance in mathematics tended to spend more time on mathematics while lower performing students demonstrated the tendency to avoid mathematics-related situations (Barkatsas et al., 2009; Sciarra & Seirup, 2008).

Summary

The theoretical framework suggests that cognitive factors have an impact on affective factors, which further influence learning behaviours and academic achievement. However, empirical evidence only supported some of these relationships. Overall, this may be due to researchers only examining the direct effect of each attitude's component on mathematics achievement, while ignoring many mediating effects. The direct relationships identified in this review showed that, in general, anxiety and gender role beliefs were negatively correlated with mathematics performance (r = -.27 to -.48/-. 21) while enjoyment, self-concept, confidence, perceived value, and behavioural intentions were positively related to achievement (r = .27 to .68/.21 to .76/.34 to .42/.11-.30/.21 to .34 respectively). As for the mediating effects, more needs to be done. For example, how appraisal of value, confidence, and self-concept mediate gender roles' effect on enjoyment and anxiety remains unstudied.

Discussion and Recommendations

Construct of Mathematics Attitudes

Research has explored many dimensions of mathematics attitudes but has not generated wide-reaching conclusions. We argue this is due to the lack of a theoretical framework for the construct of mathematics attitudes (Ma & Kishor, 1997; Zan & Di Martino, 2007). This paper applied the tripartite model (Triandis, 1971) as a theoretical framework to the concept of mathematics attitudes and therefore adopted a multidimensional definition of mathematics attitudes, which regards them as a construct with cognitive, affective, and behavioural components. Adopting the multidimensional definition of mathematics attitudes not only enables researchers to describe the term from a theoretical perspective, but also guides future research to investigate the many dimensions of the topic. Based on this definition, a tripartite construct of mathematics attitudes was proposed, where affective components contained enjoyment and anxiety; cognitive components contained value of mathematics, gender roles, confidence, and self-concept in mathematics, and the behavioural component was behavioural intentions. This tripartite construct of mathematics attitudes was rooted in a theoretical definition while also representing the most commonly measured components of mathematics attitudes, as found in research with secondary students. Thus, it helps researchers organize the many aspects of mathematics attitudes currently studied and provides researchers with a holistic picture of what mathematics attitudes are and how the sub-components relate to each other in secondary education.

With the guidance of a tripartite construct of mathematics attitudes, educators and researchers may more purposefully study which components of attitudes decrease in secondary education and which ones need to be improved. Improving mathematics attitudes not only entails increasing students' confidence in mathematics, but also involves improving students' self-perceptions with mathematics, finding utility in mathematics, improving learning experience with mathematics, and increasing the likelihood of engaging in more mathematics-related activities.

Though our tripartite construct of mathematics attitudes represents the most commonly measured components of mathematics attitudes in research with secondary students, some of the components largely overlap with what has been studied in other age levels. Articles on children's mathematics attitudes, which were excluded from this review, suggest that value, confidence, gender roles, enjoyment, and anxiety are also commonly investigated among children (Ayuso et al., 2020; Cheeseman & Mornane, 2014; Dove & Dove, 2017; Haciomeroglu, 2017; Mazzocco et al., 2012; Tossavainen & Juvonen, 2015) (see Appendix B). The term 'self-concept' and 'confidence' is often used interchangeably with children to measure their perceived efficacy for solving math problems. Merging two components into one could occur for two reasons: 1) younger children may have difficulty distinguish higher-order conceptual conclusions (Harter, 1990), and 2) when reporting on self-concept, children may have difficulty telling the real and false selves apart and their "false selves" are more reflective of parental values rather than their own perception of themselves (Harter, 1990). Similarly, articles on college/university students and adults suggest that value, confidence, self-concept, gender roles, enjoyment, anxiety, and behavioural intentions are also the most frequently tested components (Afari et al., 2013; Code et al., 2016; Eldersveld & Baughman, 1986; Hedges & Harkness, 2017; Royster et al., 1999; Serin & Incikabi, 2017; Watson, 1983) (see Appendix C). The overlapping components illustrate that mathematics attitudes share commonality across ages.

Despite the common aspects of mathematics attitudes across different age levels, some components may be more age specific. Articles with children explore a broader range of emotions rather than focusing on enjoyment and anxiety. For instance, some studies measure how much children worry about their performance in mathematics (Lauermann et al., 2017) and some explore bored, surprised, and unhappy feelings associated with mathematics (White & McCoy, 2019). All these achievements related emotions are worthy of study, as different emotions may occur during the learning process and they could mediate cognitions' impact on mathematics achievement (control-value theory, Pekrun, 2006). Therefore, different types of emotions should be considered under the affective components of mathematics attitudes, as these emotions expand the construct of mathematics attitudes, may capture learners' attitudes more precisely, and illuminate the relations between mathematics attitudes and mathematics achievement in a more detailed manner. Articles containing college/university students and adults explore perceived difficulty of mathematics (Royster et al., 1999; Serin & Incikabi, 2017). Though perceived difficulty is sometimes measured in research with primary and secondary education, it became more visible in higher education. One possible reason could be that the subject difficulty increased in higher education (Hedges & Harkness, 2017), which may cause more frustration, thus has increased the need to understand students' perceptions.

Studies on mathematics attitudes should not only focus on components in the tripartite construct, but also need to take other influencing factors into consideration. For example, factors excluded from this review (e.g., parents'/teachers' values and attitudes) may not be appropriate and accurate to represent students' own attitudes, but these factors play an important role in affecting children's attitudes (Gunderson et al., 2012). Meanwhile, genetic and environmental factors play an important role in the development of mathematics anxiety (Wang et al., 2014). Studies need to further investigate both biological pathways and individual-specific learning experiences' impact on mathematics attitudes. In addition, perception of lecturers/ teachers can influence college students' growing interest in the subject (Serin & Incikabi, 2017). Thus, future research on attitudes may measure the aforementioned factors in addition to students' attitudes, thereby having a comprehensive understanding of the development of mathematics attitudes.

Relations of Mathematics Attitudes and Mathematics Achievement

Research on the relations among mathematics attitudes and mathematics achievement were overly linear and unclear, due to lacking a theoretical framework and an inappropriate use of instruments (Ma & Kishor, 1997). This paper applied control-value theory as a framework for understanding the relation among mathematics achievement and each component of mathematics attitudes. It treated mathematics attitudes as a multifaceted concept and explored the distinctive connection between each individual component and mathematics achievement. According to control-value theory, mathematics achievement is mediated through control-value appraisal (e.g., value, self-concept, confidence) and achievement emotions (such as enjoyment and anxiety). Most of the studies in this review only assumed linear causal relationships between individual components and math achievement. The assumption of a linear relation may lead the field to overlook some critical mediating effects. As current findings suggested, how control-value appraisals mediate the effect of gender roles/beliefs on achievement emotions remains unclear. Going forward, research on mathematics attitudes can continue to look for direct effects but also needs to look at how mathematics achievement is mediated through other components.

The relations between mathematics anxiety and mathematics achievement in this review showed a negative linear correlation (Lee, 2009; Zakaria & Nordin, 2008). However, this could be more complex for two reasons: 1) the degree of anxiety was not considered, and 2) the type of anxiety was not specified. Previous studies suggest that, among young adolescents and adults who are highly motivated to learn mathematics, extreme low or high anxiety leads to poor mathematics performance, but moderate amounts of anxiety could result in optimal learning outcomes by improving attention during cognitive processing (Wang et al., 2015). Meanwhile, different types of anxiety could lead to differential impacts on achievement. Lukowski and colleagues (2019) have classified mathematics anxiety into calculation performance related anxiety, classroom related anxiety, and test related anxiety. Their study with early adolescents revealed that only calculation related anxiety significantly predicts math achievement while classroom and test related anxiety are not significant predictors (Lukowski et al., 2019). Future studies on secondary students' mathematics anxiety need to further examine levels of stress and types of anxiety to see if these forementioned patterns still hold.

Conclusion

For future work on mathematics attitudes, researchers should clearly specify the components of attitudes being explored, as this will allow others to interpret the relation between attitudes and achievement or the relations amongst each component of mathematics attitudes. Further, studies on the relations between mathematics attitudes and mathematics achievement should not only explore how each component of mathematics attitudes contributes to mathematics ability but also explore the mediating role of each component and their combinatorial contributions to mathematics achievement. As our review focuses solely on secondary education, future work is needed to systematically test whether the components in our construct of mathematics attitudes for secondary students are suitable for the study of children and adults.

Funding: The authors have no funding to report.

Acknowledgments: The authors have no additional (i.e., non-financial) support to report.

Competing Interests: The authors have declared that no competing interests exist.

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Note. Asterisk (*) marks references included in the literature review. References that were included in the review but not cited in the article are provided in Appendix D.

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Appendices

Appendix A

Table A1

Summary of the Instruments Used in Literature

Name of Scale	Cognitive Components	Affective Components	Behavioural Components	Reliability (coefficient α)	Number of Studies	Citation
Fennema-Sherman Mathematics attitudes Scales (FSMAS)	Confidence (9)[a], Value (7), Gender roles (7), Attitude towards success (6), Perception of parents/ teacher's attitudes (5)	Anxiety (3), Affect (3)		NA; .84; .79-.96; .92; .86-.93; .86-.98; .84-.94; .87-.89; .87-.93; .66-.68	10	Broadbooks et al. (1981) Casem (2016) Fennema and Sherman (1976) Ganley and Vasilyeva (2011) Hyde et al. (1990) Iben (1991) Norton and Rennie (1998) Pedro et al. (1981) Sherman (1982) Yang (2015)
Attitudes Toward Mathematics Inventory (ATMI) (by Tapia & Marsh, 2004)	Confidence (5), Value (5)	Enjoyment (6), Motivation (5)		.88-.95; .93; .71-.90; NA; .86; .88-.95	6	Awofala et al. (2013) Lim and Chapman (2013) Mavridis et al. (2017) Mirza and Hussain (2018) Mohr-Schroeder et al. (2017) Tapia and Marsh (2004)

Name of Scale	Cognitive Components	Affective Components	Behavioural Components	Reliability (coefficient α)	Number of Studies	Citation
Aiken's Math Attitude Scale	Value (4)	Enjoyment (4)		.87-.93; .85-.95; .77-.82; .68-.88	4	Adwere-Boamah (1986) Sarouphim and Chartouny (2017) Tran (2012) Watson (1983)
The Mathematics Attitude Scale developed by Aşkar (1986)		Enjoyment (3)		.93; .96; .93	3	Dursun (2015) Erdik (2018) Idil et al (2016)
Sandman's Mathematics Attitude Inventory (MAI)	Perception of math teacher (2), Value (2), Self-concept in math (2)	Anxiety (2), Enjoyment (2), Motivation (2)		.68-.89	2	Rech (1994) Sandman (1980)
Mixed	Value (3), Self-concept (2), Confidence (1), Gender roles (1)	Enjoyment (2)	Behavioural intentions (1)	.58-.60; .60-.73; NA	3	Gwizdala and Steinback (1990) Kiwanuka et al. (2017) Yáñez-Marquina and Villardón-Gallego (2016)
Not Clear					7	Bilican et al. (2011) Kamoru and Ramon (2017) Martinez (2017) Mukherjee and Umar (1978) Muthulakshmi and Veliappan (2016) Oyedeji (2017) Yasar (2016)
Modified from previous literature	Value (9) Confidence (5) Gender roles (4) self-concept (1), attention (1), Perceived difficulty (1), Attitudes towards school (1), Learning (1), math teaching (1), Teacher's attitudes (1), Nature of math (1), Attitudes towards school (1)	Enjoyment (8) Anxiety (8) Motivation (2), Feelings (1),	Behavioural intentions (3)	.64; .96; .83; NA; NA; NA; NA; .94; .89; NA .85; NA; .85-.90; .54; .79; .52-.57; NA; .73; NA; .96; NA; .44-.91; .96	23	Arhin (2015) Arslan et al. (2012) Awofala et al. (2013) Aydın (2015) Elçi (2017) Geiser (1999) Kontas (2016) Koyuncu and Dönmez (2018) Mallam (1993) Mandina et al. (2013) Murimo (2013) O'Reilly (1980) Rice et al. (2013) Fisher and Rickards (1998) Ritzhaupt et al. (2011) Sanchal and Sharma (2017) Sengül and Dereli (2013) Simsek (2016) Soliman and Hilal (2016) Swetz et al. (1983) Van Eck (2006) Mumcu and Aktas (2015) Yenılmez (2007)
PISA 2012/2005	Self-concept (2)			NA; .86	2	Cheung et al. (2018) Perry et al. (2016)
TIMSS 2007/2011/1990-2007/2009 /2003/	Value (6), Confidence (6)	Enjoyment (6)		NA 86; .84-.93; NA; .73-.86; .83-.93	6	Bilican et al. (2011) Choi and Chang (2011) Hwang et al. (2017) Ruthven (2011) Smith et al. (2014) Vandecandelaere et al. (2012)
Self-developed	Value (13), Gender roles (8); Confidence (4) Self-concept (8), Perception of difficulty (3), Parents' perception (3),	Enjoyment (13), Boredom (4), Anxiety (5), Feelings (1),	Behavioural intentions (7); More attention (1);	NA; .91; NA; .65-.84; NA; .93;	24	Brandell and Staberg (2008) Butty (2001) Charles et al. (2014) Cheung (1988) Elliott et al. (2001) Eskici et al. 2017

Name of Scale	Cognitive Components	Affective Components	Behavioural Components	Reliability (coefficient α)	Number of Studies	Citation
	Teachers' impact (3),			.94;		Etuk et al. (2013)
	Perceived control (1),			NA;		Funkhouser (1993)
	Rules (1),			NA;		Haladyna et al. (1983)
	Intention (1),			.84-.89;		Hemmings et al. (2011)
	Home-support (1),			NA;		Higgins (1997)
	Home-process (1),			.83;		Ifamuyiwa and Akinsola (2008)
	Society (1),			.58-.83;		Jacobs (1991)
	Fatalism (1)			.65;		Jurdak and Abu Zein (1998)
				.89;		Lipnevich et al. (2011)
				NA;		Ma (1997)
				NA;		Minato and Yanase (1984)
				.60-.65;		Mutohir et al. (2018)
				NA;		Steinback and Gwizdala (1995)
				NA;		Thomas (2000)
				.34-.87;		Tocci and Engelhard (1991)
				.91;		Yenılmez (2007)
				.84		Zakariya (2017)

[a]The number in the brackets following each component represents the frequency of that component being applied.

Appendix B

Table B1

Summary of Mathematics Attitude Components Used in Primary Education

Citations	Cognitive Components	Affective Components	Behavioural Components	Type of Scale
Ayuso et al. (2020)	Confidence Value	Anxiety		Bi-dimensional
Cheeseman and Mornane (2014)	Confidence Value			Uni-dimensional
Dove and Dove (2017)		Anxiety		Uni-dimensional
Lauermann et al. (2017)	Value Self-concept	Worry		Bi-dimensional
Rech (1994)	Value Self-concept	Enjoyment Anxiety	Behavioural Intentions	Multidimensional
Tossavainen and Juvonen (2015)	Value	Enjoyment		Bi-dimensional
White and McCoy (2019)		Worry Boredom Surprise Happiness		Uni-dimensional
Haciomeroglu (2017)	Value Confidence/Self-concept	enjoyment	Behavioural Intentions	Multidimensional
Mazzocco et al. (2012)	Perceived difficulty Value	Enjoyment (likability)		Bi-dimensional

Appendix C

Table C1

Summary of Mathematics Attitudes Components Used in Higher Education

Citations	Cognitive Components	Affective Components	Behavioural Components	Type of Scale
Afari et al. (2013)	Confidence	Enjoyment		Bi-dimensional
Code et al. (2016)	Confidence Value Math beliefs		Behavioural Intentions	Bi-dimensional
Eldersveld and Baughman (1986)	Confidence	Anxiety		Bi-dimensional
Hedges and Harkness (2017)	Nature of statistics Pervious experience		Behavioural Intentions	Bi-dimensional
Royster et al. (1999)	Value Self-concept Confidence Perceived difficulty	Enjoyment Scariness	Behavioural Intentions	Multidimensional
Serin and Incikabi (2017)	Perceived difficulty Interest			Uni-dimensional
Watson (1983)	Value	Enjoyment		Bi-dimensional

Appendix D

Additional Articles

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