Exploring K–12 Mathematics Teachers' Identity and Beliefs About Mathematics and Teaching

Jennifer Cribbs
Oklahoma State University

Juliana Utley
Oklahoma State University

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Research has indicated a need for mathematics-specific affective measures and reported a lack of research exploring how these beliefs relate to one another, specifically with identity measures. Thus, the aims of this study are: (1) to validate measurement items for a mathematics teacher identity scale and a mathematics teaching philosophy scale, and (2) to explore correlations that may exist between these and other mathematics-specific beliefs. Exploratory factor analysis was conducted to provide evidence to support the inclusion of instrument items measuring both the mathematics teacher identity and mathematics teaching philosophy scales. Additionally, results indicated strong or moderate correlations among many of the identity and beliefs measures, such as mathematics identity and mathematics teacher identity. Mathematical mindsets, however, were either weakly correlated or not significantly correlated with all other measures. This study extends previous research on the understanding of the relationships among mathematics specific affective measures.

Keywords • mathematics teacher education research • mathematics identity • teacher identity • mathematics teaching philosophy • beliefs•

Introduction

Although prior research notes the importance of teachers' beliefs on their practice (Wilkins, 2008), there is little research exploring how these beliefs relate to their content-specific identity. Some work with elementary teachers notes the complex interactions between K–8 teachers' professional identity and practice (Aguirre et al., 2013), finding that mathematics teacher identity influences their views about their practice and their students' learning experiences in the classroom. Aguirre and colleagues made the importance of this line of work apparent by stating that "what gets taught in the mathematics classroom shapes the mathematics identities of both students and teachers" (2013, p. 37). The National Council of Teachers of Mathematics (NCTM) also positioned identity as an integral component of teacher practice as evident through a variety of published statements, accreditation standards, and books (e.g., Larson, 2016; NCTM, 2014).

In addition to connecting teacher identity with their practice and student identity, researchers have used identity as a lens for exploring teacher attrition and retention. This line of research is particularly relevant given the teacher shortage in the United States (Nguyen et al., 2022;) and worldwide (United Nations Educational, Scientific and Cultural Organization (UNESCO), 2022). With mathematics teacher attrition being higher than in other disciplines (Grillo & Kier, 2021), content-specific measures for exploring identity could aid future work exploring these connections. Prior research on science identity has shown that professional teacher identity influences teacher attrition (Hong, 2010); however, that research did not explore content-specific identity, which might provide further insight into teacher retention. In Hannula's (2016) review of identity research with teachers, a recommendation was made for pursuing research that explores "intersections between identity and other affect-related constructs" (p. 25). While some of this work has already begun, particularly with qualitative studies, quantitative research in this area is more limited. Lutovac and Kaasila (2019) noted that work in teacher identity could be extended by using both qualitative and quantitative approaches, providing "a more versatile view of the phenomenon, as well as a greater generalisation of findings" (Kelle & Buchholtz, 2015, p. 513). In addition, the current study focuses on mathematics-specific rather than general beliefs, addressing a weakness that was noted concerning current research related to affective measures (Hannula, 2016). Given that disciplines have their own language, conventions, and practices, having measures that align with the discipline is important. This was made apparent in Shulman's (1986) work distinguishing subject matter and pedagogical content knowledge. Baumert et al. (2010) found that pedagogical content knowledge was a stronger predictor of student learning than content knowledge. These studies make a case for considering the content-specific nature of teacher beliefs, such as mathematics teacher philosophy, which allows for a better understanding of the phenomena or construct being explored. Thus, the aim of this study is to: (1) provide validity evidence for two mathematics-specific constructs—mathematics teacher identity and mathematics teaching philosophy, and (2) explore correlations that may exist among mathematics teacher identity, mathematical teaching philosophy, and other mathematics-specific measures—mathematics identity, mathematical mindset, mathematics self-efficacy, and mathematics anxiety.

Background Literature

Theoretical Framework for Mathematics Teacher Identity

Identity is a powerful construct because it includes a sociocultural perspective, which is often neglected in other affective measures. In situating professional identity, Beijaard et al. (2004) noted that researchers have typically defined the construct as an ongoing process involving both the professional and personal identities of an individual. Identity development is both internally and socially informed. Teachers' professional identity also gives insight into teachers' instructional choices. For example, Jong (2016) noted that "teaching practices are then enactments of an individual's combined teaching identity and experiences" (p. 308) when conducting a case study with a novice elementary teacher and her enactment of reform-based practices in her classroom. Hong (2010) also found that teachers' professional identity related to teacher retention, where one component of teacher identity, teacher burnout, connected closely to teachers leaving the profession.

Much of the previous research in the field of mathematics education focused on teachers' participation in a community of practice or the process of becoming a teacher, taking a qualitative approach using narratives (Aguirre et al., 2013) or photo-elicitation (Lembrér, 2019). In a review of research on professional identity in mathematics education literature, only seven out of the 48 studies selected included questionnaires or surveys, and of those identified, other methods, such as open-ended questions or rank tasks, were used rather than a measure for professional identity (Lutovac & Kaasila, 2019). Other lines of research on the topic adopt a general rather than discipline-specific identity measure (Richter et al., 2021). However, given the discipline-specific training and practice of teachers, a better understanding of the relationship between professional and content-specific identities is needed. Cross Francis et al. (2018) made this clear when exploring tensions experienced by teachers as they navigate what it means to be a mathematics teacher in addition to teaching a variety of other disciplines. Other research has noted the important role that content-specific identity has on individuals' behaviours and actions (Cribbs, 2021a; Thamotharan & Hazari, 2017). While all these methods are important contributions to the field, a measure for mathematics teacher identity could provide another useful tool for educators and researchers. Thus, this study explores mathematics teacher identity through a discipline-specific measure by taking a snapshot of teachers' current professional mathematics identity. We contend that this is an important distinction as a teacher's professional identity might differ across content areas. For example, an elementary teacher might have a different perception of their professional identity as it relates to reading versus mathematics. Drawing on prior work, we propose a nuanced way to explore professional identity that captures the content-specific nature of identity for mathematics teachers (see Figure 1).

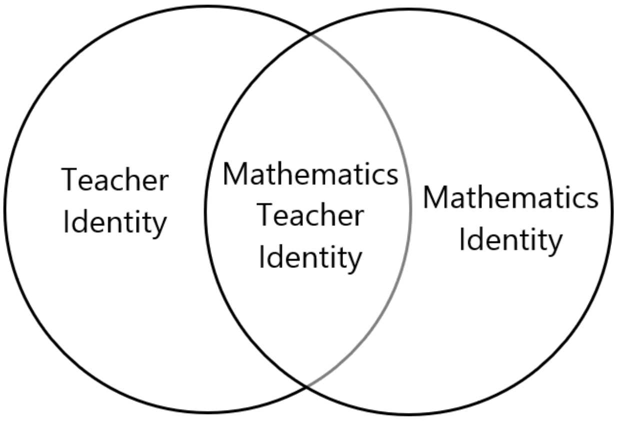

Figure 1. Theoretical framework for mathematics teacher identity.

In conceptualizing mathematics teacher identity, we draw on Gee's (2000) work framing identity in terms of being a certain kind of person and Cobb and Hodge's (2011) extension of that work into specific aspects of identity, with this study focusing on core identity. This approach aligns with a macro-identity approach (global view; Lichtwarck-Aschoff et al., 2008), where identity thickens as experiences accumulate (Cribbs et al., 2022; Holland & Lave, 2001).

Drake et al. (2001) stated that teacher identities are situated within their role as a teacher and learner. Further, teacher identity is "their sense of self as well as their knowledge and beliefs, dispositions, interests, and orientation towards work and change" (Drake et al., 2001, p. 2). Reflecting this definition as well as the discipline-specific nature of mathematics teacher identity, we view the construct as a teacher's sense of self as it relates to the individual's knowledge, beliefs, and interests as a mathematics educator. The mathematics teacher identity measure was developed based on the discipline-specific measure for identity. Drawing on prior work conceptualizing mathematics identity (Cribbs et al., 2015) and science teacher identity, the construct of mathematics teacher identity is comprised of three sub-constructs:

- recognition (how individuals view themselves and how they perceive others viewing them in relation to being a mathematics teacher),
- interest (individual's desire or curiosity to think and learn about teaching mathematics), and
- competence/performance (individual's beliefs about their ability to understand and perform as a mathematics teacher).

In combination, these sub-constructs provide a picture of an individual's mathematics teacher identity.

Theoretical Framework for Mathematics Teaching Philosophy

Preservice teachers bring to their teacher preparation program an image of teaching based on their experiences as a student (Ross & Bruce, 2007) and most of these preservice teachers have experienced mathematics instruction that was teacher-centered (Reeder et al., 2010). Further, Kayan et al. (2013) suggested that a teacher's beliefs are processed and filtered through their experiences with learning and teaching mathematics and shape their teaching philosophy. Additionally, researchers (e.g., Bowne, 2017) indicated that a teaching philosophy is an individual's beliefs and values about teaching and learning that develops from a reflection on their own experiences. Thus, in this paper, teaching philosophy is defined as a teacher's beliefs about teaching and how that view is applied in the classroom.

The mathematics learning experiences of students are influenced by their interactions with their teachers (Ball & Forzani, 2011). A teacher's teaching philosophy has been shown to relate to their practice and student performance. Teachers who exhibit more student-centered beliefs about teaching and learning are more inclined to adopt reform-based curricula (Roehrig & Kruse, 2005). Teacher beliefs influence: 1) "the decisions that they make about the manner in which they teach mathematics" (National Council of Teachers of Mathematics [NCTM], 2014, p. 10), 2) the expectations they have of their students which are directly correlated with their students' learning outcomes (Rosenthal, 1994), and 3) the learning environment (Kagan, 1992). Additionally, Utley et al. (2020) found that about one-third of the preservice elementary teachers' drawings in their study reflected productive student-centered teaching philosophy.

Exploring a teacher's teaching philosophy has typically been done using teaching philosophy statements in teacher preparation programs. There is, however, a need for a way to gather quantitative evidence about their teaching philosophy. This work could aid researchers and educators in efficiently assessing teachers' teaching philosophy and open up opportunities for additional research studies using quantitative approaches exploring the construct. The research reported in this paper was informed by Utley et al.'s (2020) Draw a Mathematics Teacher Test Rubric (DAMTT-R) used to explore how teachers envision their mathematics classroom, and NCTM's (2014) *Principles to Action* beliefs about teaching and learning mathematics. To conceptualise a teacher's teaching philosophy, the measure created asks for teachers to indicate their level of agreement using a semantic differential scale with student-centered and teacher-centered statements. Using a "continuum" has the potential to assess how teachers might situate their beliefs that align more to their core beliefs than using multiple philosophy measures to report different levels of related beliefs.

Relationships Among Mathematics Teacher Identity and Other Affective Measures

In addition, to developing and providing validity evidence for the two constructs, mathematics teacher identity and mathematics teaching philosophy, this study explores potential connections between these constructs as well as among other affective measures. According to Hannula (2012), affective measures are inclusive of three dimensions: type of affect, theories related to the relative stability of affect, and the enactivism and system theory (physiological, psychological, and social) used in framing affect. Under this umbrella, all the measures used in the current study, including identity, are categorised as an affective measure. In this section, we aim to highlight potential connections between mathematics teacher identity and mathematics identity, mathematical mindset, self-efficacy, and mathematics anxiety.

Mathematics teacher identity and mathematics identity

In this study, we define mathematics identity as how individuals see themselves in relation to mathematics, based on their perceptions and navigation of everyday experiences with mathematics (Enyedy et al., 2006). This definition aligns with the framing and conceptualisation of mathematics teaching philosophy as detailed in the theoretical framework. Previous research noted the independence of content-specific identity and teacher identity. While this case has been made for science teachers (Rushton & Reiss, 2021), there is the potential to make a similar case for mathematics teachers. Thus, exploring mathematics teacher identity in connection to mathematics identity could help researchers better understand the type of relationship that exists between these identities.

Mathematics teacher identity and mindset

Mathematical mindset builds from Dweck's (2008) general mindset work, which is defined as an individual's beliefs about the malleability of mathematics intelligence. While work on mathematical mindset specifically is still a relatively new area of research, there is evidence that an individual's mindset influences their identity. For example research found that mathematical mindsets predict mathematics identity for undergraduate students (Cribbs et al., 2021b). The Cribbs et al. study provided a precedent for theorising a connection between other identity measures and mindset, as done in the current study. Additionally, Lutovac and Assunção Flores (2021) stated that teacher identity is connected to teachers' experiences with failure. They indicated that mindset helps to make sense of this aspect of their identity as it connects with their resilience. These studies make a case for a connection between teacher identity and mindset.

Mathematics teacher identity and self-efficacy

Building on Bandura's (1997) theory, mathematics self-efficacy is defined as one's beliefs about their ability to perform a mathematics task. In a review of literature for teacher identity, Hanna et al. (2019) found that seven of the 20 studies included had a measure for self-efficacy, providing evidence that researchers feel these measures are connected. That review also noted the lack of theoretical explanation for this connection. Another study by Marschall (2022) provided some understanding of this relationship indicating that teacher identity was intricately influenced by self-efficacy for one mathematics preservice teacher. Marshall also stated that "social verification" from the teacher community was necessary to support the preservice teacher's sense of identity and self-efficacy (p. 733). These studies provide support for a potential connection between mathematics teacher identity and self-efficacy. Studies using larger samples are needed to explore claims made by Marschall (2022).

Mathematics teacher identity and mathematics anxiety

Mathematics anxiety is defined as an unpleasant feeling about doing mathematics (Ashcraft, 2002). Prior research noted a connection between preservice teacher identity and their anxiety (Lin et al., 2017) as well as mathematics teacher identity and mathematics teaching anxiety (Uygun-Eryurt, 2021). The way these constructs are connected is not entirely clear, with some evidence of a moderating role with other aspects of teachers' experiences as well as the direction of the relationship (Lin et al., 2017). Other research that noted a relationship between content-specific anxiety and identity (e.g., Cribbs et al., 2021b) provided additional evidence for exploring a connection between mathematics teacher identity and mathematics anxiety.

Relationships Among Mathematics Teacher Philosophy and Other Affective Measures

The current study also explores potential connections among mathematics teaching philosophy and other affective measures. Specifically, this section will highlight potential connections among mathematics teaching philosophy and mathematics identity, mathematical mindset, self-efficacy, and mathematics anxiety.

Mathematics teaching philosophy and mathematics identity

As a teacher's teaching philosophy influences their classroom practice (Opdenakker & Damme, 2006), it is important to explore this construct along with other affective constructs. Vermote et al. (2023) found that teachers with a strong sense of professional identity adopted more motivational styles of teaching. Specifically, teachers with a stronger sense of identity "reported acting more autonomy supportive and structuring in the classroom" as well as "tend[ing] to emphathize more with students' needs, interests, and concerns" (p. 18). Thus, exploring mathematics teaching philosophy in connection to mathematics identity could help researchers understand better the type of relationship that exists between these constructs.

Mathematics teaching philosophy and mindset

As with identity, research has found a connection between teachers teaching style and their perceptions of their students' mindset (Vermote et al., 2020). Likewise, other research found that teachers with a more fixed mindset "were more likely to adopt a demotivating style" of teaching, with gifted and traditional students alike (Sypré et al., 2023, p. 18). Much of the work in this area has focused on higher education, so additional work related to K–12 will aid the field's understanding of these connections.

Mathematics teaching philosophy and self-efficacy

Mathematics self-efficacy and mathematics anxiety have a large body of research showing a connection between these constructs and student beliefs (e.g., Midgley et al., 1989), student achievement (e.g., Caprara et al., 2006), and teachers' instructional practices (e.g., Ghaith & Yaghi, 1997), which makes it an important construct to explore as part of the current study. One study found that preservice teachers' perceptions of teaching style as predictive of their self-efficacy (González et al., 2018). Other research supports this relationship (Baleghizadeh & Shakouri, 2017) as well as correlating teaching orientation with self-efficacy (van Daal et al., 2014). These studies provide evidence for a potential relationship between teaching philosophy and self-efficacy.

Mathematics teaching philosophy and mathematics anxiety

Much of the research connecting teaching philosophy with mathematics anxiety relates to teachers' teaching style and students' mathematics anxiety (e.g., Kelly et al., 2019). Other literature, however, noted relationships with other constructs of interest such as self-efficacy (Patkin & Greenstein, 2020) and mathematics identity (Cribbs et al., 2021b). Further research exploring a connection between mathematics teaching philosophy and mathematics anxiety will add to our understanding of these constructs.

Research Questions

Exploring mathematics teacher identity, mathematics teaching philosophy, mathematics identity, mathematical mindset, mathematics self-efficacy, and mathematics anxiety constructs in combination has the potential to glean a better understanding of how they are related and builds on existing research in the field. The research questions guiding this study are:

(1) *To what extent do the survey items measure the construct of mathematics teacher identity for in-service teachers?*

(2) *To what extent do the survey items measure the construct of teachers' teaching philosophy?*

(3) *Are teachers' self-perceptions and beliefs about mathematics and teaching mathematics correlated?*

Methods

This study employed an online survey design, collecting data with a large sample of teachers at one point in time.

Data Collection

At the end of the Spring semester, a survey was sent to all potential mathematics teachers in a mid-western state in the United States based on contact information provided by the State Department of Education. A total of 17,444 emails were sent to elementary, middle grades, and secondary teachers; however, all elementary teachers, some of whom did not teach mathematics, were included in this initial email as the researchers had no way of determining which teachers did or did not teach mathematics. There were 1,385 bounced emails and after one initial email request and one reminder email, a total of 1,931 participants responded. The first question on the survey asked participants if they taught mathematics. There were 155 teachers who selected the option of not being a mathematics teacher and were automatically sent to the end of the survey thanking them for their participation. In 41 of the responses, the teacher did not respond to any questions. Out of the remaining 1,735 responses, 1,499 completed enough items to be included in the study.

Participants

The respondents were 94.1% female, 5.6% male, and 0.1% other, with 0.1% not reporting their gender. In terms of race and ethnicity, respondents were 83.6% White, 6.7% Multicultural, 5.6% Asian, 2.6% African American, 1% Other, and 0.5% Pacific Islander, with 3.1% of the participants identifying as Hispanic. Although the sample did not exactly represent the teacher demographics for the state, it was similar with 83% of teachers identifying as White, 8.5% as American Indian, 4% as multicultural, 3% as African American/Black, less than 1% as Asian, and 1.5% as Hispanic (Oklahoma State Report Card, 2023). Participants' ages ranged from the 20s to 71 plus years, and they had university degrees ranging from a bachelor's to a doctorate degree. Years of teaching experience reported by participants ranged from 1 to 49 years with a mean age of 13.3 years. In terms of grade level that participants were teaching, 603 nominated K–2, 889 nominated 3rd–5th, 359 nominated 6th–8th, and 85 nominated 9th–12th. As there was overlap in grade levels taught, the teaching numbers add up to more than the total number of participants.

Measures

Mathematics identity

Mathematics identity (11 items, 5-point Likert scale) was measured using items developed and tested in prior research (see Cribbs et al., 2015). This construct was comprised of three sub-constructs including interest (e.g., "I enjoy learning math"), recognition (e.g., "I see myself as a math person"), and competence/performance ("I understand the math I have studied"). Responses ranged from 1 to 5 with the higher the mean, the more a person identifies with being a "math person". Cronbach's alpha, a way of testing the internal consistency of the construct for mathematics identity, was .93.

Mathematical mindset

Mathematical mindset items (4 items, 5-point Likert scale) drew from prior research (De Castella & Byrne, 2015; Degol et al., 2018). Responses can range from 1 (Fixed mindset) to 5 (Growth mindset), with items such as "No matter who you are, you can significantly change your math intelligence level" and "You can change even your basic math intelligence level considerably." The higher the mean, the more the responses are aligned with a growth mindset. Cronbach's alpha for mathematical mindset was .89.

Mathematics teacher identity

Mathematics teacher identity (13 items, 5-point Likert scale; see Appendix A) includes the same three sub-constructs as mathematics identity, interest (e.g., "I enjoy teaching others math"), recognition (e.g., "My family sees me as good at teaching math"), and competence/performance ("I am confident I can teach math well") but focused on mathematics teaching. Responses ranged from 1 to 5 with the higher the mean, the more a person identifies as being a mathematics teacher. Cronbach's alpha for mathematics teacher identity was .95.

Self-efficacy for teaching mathematics instrument

The 5-point Likert scaled Self-efficacy for Teaching Mathematics Instrument (McGee & Wang, 2014) was used to measure efficacy for pedagogy in mathematics (EPM, 7 items, "To what extent can you motivate students who show low interest in mathematics?") and efficacy for teaching mathematics content (ETMC, 15 items; "How well can you teach students to … Represent numbers on a number line."). Responses for EPM and ETMC ranged from 1 to 5. The higher the mean score, the more efficacious the teacher felt about teaching mathematics. Cronbach's alpha for the overall self-efficacy for teaching mathematics construct was .95.

Mathematics anxiety scale: Revised

The 5-point Likert scaled mathematics anxiety rating scale-revised (Hopko, 2003) with two sub-constructs—learning mathematics anxiety (LMA, 8 items) and mathematics evaluation anxiety (MEA, 4 items)—was used in this study (Hopko, 2003). Participants responded to the question "How anxious would each of the following activities make you?" with items such as "Looking through the pages in a math text" for LMA and "Thinking of an upcoming math test one day before." The responses for LMA and MEA ranged from 1 to 5. The higher a mean score, the higher the level of anxiety identified. Cronbach's alpha for the overall mathematics anxiety was .94.

Mathematics teaching philosophy scale

A nine-item, researcher-developed instrument (see Appendix B for the final 8-item version) was used to measure the teachers' mathematics teaching philosophy. This instrument used a semantic differential scale to measure teachers' beliefs about effective mathematics practices drawing on the *Principles to Actions* text published by the National Council of Teachers of Mathematics (NCTM, 2014) and related work (Utley et al., 2020). Responses for each item can range from 1 (teacher-centered) to 5 (student-centered). For example, an item asked participants to indicate where they were on a continuum in response to the statement "Teacher is the sole authority source of knowledge. Knowledge is transmitted from teacher to student (teaching is telling)" on the teacher-centered side and "Teacher challenges and guides student teaching toward understanding. Knowledge is subjective and students construct their own knowledge through interactions with others and reflecting upon their experiences" on the student-centered side. The higher the mean responses, the more consistently the beliefs aligned with a student-centered mathematics-teaching philosophy. Cronbach's alpha for Mathematics Teaching Philosophy was .85.

Data Analysis

All statistical analyses were conducted using *R* statistical software package (Version 4.0.3). Exploratory factor analysis (EFA) was used to answer Research Questions 1 and 2, assessing how well survey items aligned with the construct of mathematics teacher identity and mathematics teaching philosophy. If survey items aligned with the theorised construct, it would provide evidence of construct validity. Promax rotation was used for both EFA as it is theorised that the items are correlated.

Next, a Pearson correlation test was conducted to address Research Question 3 to assess the level of correlation between all the affective measures (mathematics identity, mathematics teacher identity, mathematical mindset, mathematics self-efficacy, mathematics anxiety, and mathematics teaching philosophy).

Results

Mathematics Teacher Identity Exploratory Factor Analysis

To determine whether the mathematics teacher identity construct was appropriate to use with K–12 in-service teachers, an EFA was conducted using promax rotation. Before running the EFA, a correlation test between items found that all correlations were above the recommended .30, as expected for items that measure the same construct (Field et al., 2012). The Kaiser-Meyer-Olkin measure of sampling adequacy was .95, with individual items at .93 to .97, well above the recommended .50 and considered "marvellous" at or above .90 (Kaiser, 1974). Additionally, Barlett's test of sphericity was significant (χ^2(12, N = 1499) = 302, *p* <.001), indicating that the items are acceptable for conducting the EFA. A Scree plot (see Figure 2) and parallel analysis determined that three factors and one component should be retained. This corresponds to one factor (mathematics identity) with three sub-factors (recognition, interest, competence/performance).

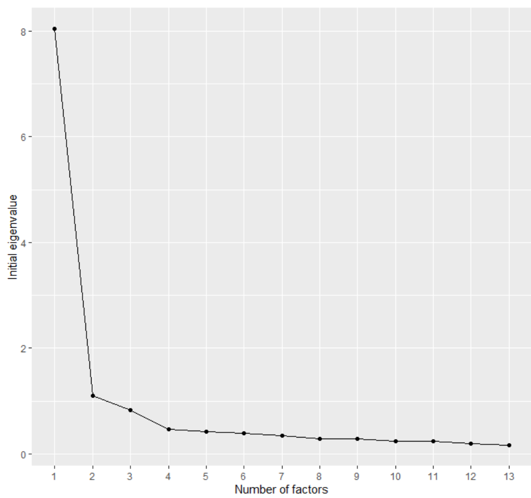

Figure 2. Scree Plot for mathematics teacher identity items.

Results for the EFA also support the inclusion of three factors, reported in Table 1 and Figure 3, with fit indices within recommended levels (Schumacker & Lomax, 2016) and items having a loading score of .43 or greater. Additionally, items loaded, as theorised, on the three sub-constructs (recognition, interest, and competence/performance). Figure 2 also shows the correlations between sub-constructs with the three sub-constructs strongly correlated at or above .70. The sub-construct recognition and competence/performance explained the same percent of variance at 25%, explaining 50% of the cumulative variance. Interest explained 19% of the variance, with the three factors explaining 69% of the cumulative variance. These three factors had an Eigenvalue of greater than one, recognition = 3.29, competence/performance = 3.30, and interest = 2.46, providing additional evidence that they should be retained as separate factors.

Table 1
EFA Results for Mathematics Teacher Identity

Latent Variable	Item no.	Survey Item	Factor 1 Loading	Factor 2 Loading	Factor 3 Loading
Recognition		I see myself as a math teacher.	.74		
(%VE = 25)		My family sees me as good at teaching math.	.90		
		My friends/colleagues see me good at teaching math.	.87		
		Others ask me for help in math	.69		
Interest		I enjoy teaching others math.		.43	
(%VE = 19)		Thinking about ways to teach math topics is fun.		.84	
		It is interesting to observe … their thinking in math.		.82	
		I am passionate about sharing ideas in math ….		.70	
Competence/		I know the steps … to teach math concepts effectively.			.81
Performance		I am confident I can teach math well.			.78
(%VE = 25)		I understand math … to be effective when teaching …			.87
		… I usually know how to help the student understand …			.82
		I know how to turn students on to math.			.55

Index	Actual	Recommended
RMSR	.02	<.05
RMSEA	.07	.05 to .08
TLI	.96	>.95

Note: VE = Variance Explained; RMSR = root mean square residual; RMSEA = root mean square error of approximation; TLI = Tucker-Lewis Index

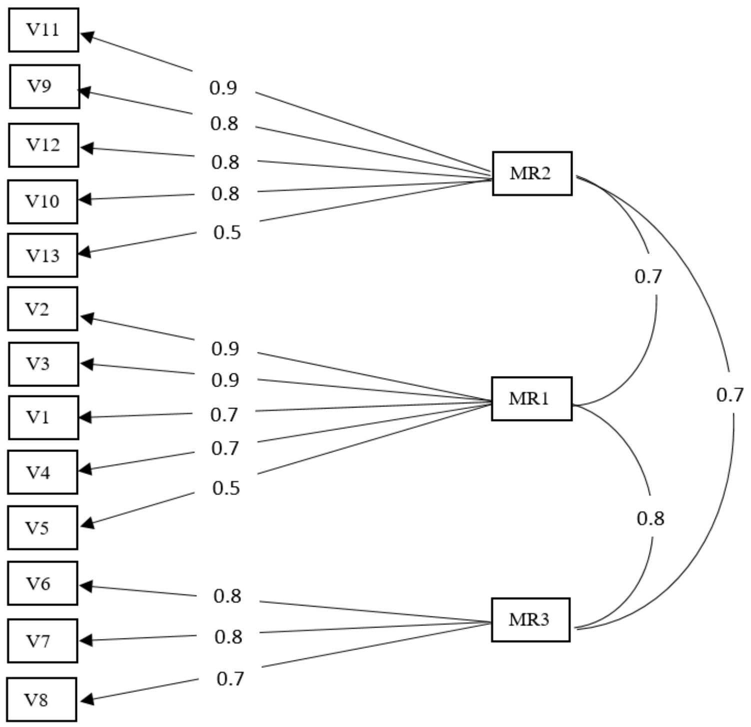

Figure 3. Results of EFA for mathematics teacher identity items.

Mathematics Teaching Philosophy Exploratory Factor Analysis

To determine how well items aligned with the mathematics teaching philosophy construct, an EFA was conducted using promax rotation. A correlation test between items found that Item 9 (The curriculum is focused on specific outcomes …) had consistently lower correlations (below .30) with the other items on the survey. Based on this finding and additional discussion about the item, the research team removed it from further analysis as the low correlation indicated the item may not have measured the same factor, leaving eight items in the measure. Additionally, Item 2 (Students lack knowledge …), which had a correlation of .27 with Item 6 (Assessment is primarily focused on accountability…), and a correlation of .29 with Item 7 (Teacher expects students to work individually …). The research team, however, chose to leave Item 2 in the measure as the correlations were close to the recommended .30. The Kaiser-Meyer-Olkin measure of sampling adequacy was .91, with individual items at .88 to .93, well above the recommended .50 and considered "marvellous" at or above .9 (Kaiser, 1974). Additionally, Barlett's test of sphericity was significant ($\chi^2(7, N = 1499) = 36$, $p < .001$), indicating that the items are acceptable for conducting the EFA. A Scree plot (see Figure 4) indicates one factor should be retained. A parallel analysis, however, determined that two factors and one component should be retained. Based on these results and the fact that only one factor had an Eigenvalue greater than 1, the research team opted to move forward with one factor. Results for the EFA are reported in Table 2, with fit indices within recommended levels (Schumacker & Lomax, 2016) and items having a loading score of .47 or greater, with items explaining 43% of the cumulative variance.

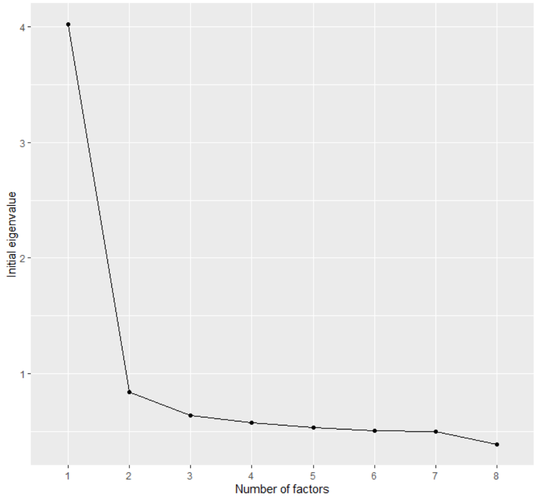

Figure 4. Scree Plot for Mathematics Teaching Philosophy items.

Table 2
EFA Results for Mathematics Teaching Philosophy

Survey Item	Factor Loading
Teaching is telling … Teacher challenges and guides…	.67
Students lack knowledge … Students are capable of creating their own understanding …	.47
Learning is about acquisition of facts … Learning is an active process …	.66
All classroom interactions are initiated … Classroom interactions involve a combination …	.73
Assessment of mathematical understanding … Assessment of mathematical understanding …	.74
Assessment is primarily focused on accountability … Assessment is primarily focused on …	.63
Teacher expects students to work individually … Teacher encourages collaboration …	.68
Teacher initiates activities … Teacher focuses on student questions …	.66

Index	Actual	Recommended
RMSR	.03	<.05
RMSEA	.06	.05 to .08
TLI	.96	>.95

Note: RMSR = root mean square residual; RMSEA = root mean square error of approximation; TLI = Tucker-Lewis Index

Correlation Analysis Between Constructs

All the mathematics constructs were significantly correlated with each other (see Table 3). Specifically, mathematics identity was strongly, positively correlated with mathematics teacher identity, $r(1497) = 0.75$, $p < .001$, which is not surprising given that these constructs are built on the same theoretical framework. Both mathematics anxiety measures were also moderately, negatively correlated with mathematics identity (MA – $r(1497) = –0.64$, $p < .001$) and mathematics teacher identity (MA – $r(1497) = –0.55$, $p < .001$). This finding is consistent with other research noting that mathematics anxiety is significantly negatively correlated with mathematics identity for undergraduate students (Cribbs et al., 2021b). Mathematics teacher identity was also moderately, positively correlated with both measures for self-efficacy for teaching mathematics $r(1497) = .64$, $p < .001$. Given that mathematics self-efficacy and mathematics identity have been shown to be strongly correlated (Cribbs et al., 2021b), this finding is consistent with the theoretical underpinnings for the mathematics teacher identity measure.

Teaching philosophy had the weakest correlation with the rest of the constructs (r between .05 and .19). Mathematical mindset also had weak correlations with most of the other constructs (r between .19

and .39). The strongest correlation with mathematical mindset was with mathematics teacher identity, but even this correlation was low, $r(1497) = .39$, $p < .001$.

Table 3

Correlation Test Results

Construct	MathID	Mindset	MTID	EPM	ETMC	LMA	MEA	MTP
MathID	-							
Mindset	.34***	-						
MTID	.75***	.39***	-					
EPM	.39***	.31***	.60***	-				
ETMC	.45***	.27***	.57***	.56***	-			
LMA	–.63***	–.23***	–.55***	–.32***	–.47***	-		
MEA	–.58***	–.19***	–.4****	–.28***	–.40***	.82***	-	
MTP	.06	.19***	.09**	.18***	.12***	–.07	–.04	-

**p <0.01 ***p <0.001

Note: MathID = Mathematics Identity; Mindset = Mathematical mindset; MTID = Mathematics Teacher Identity; EPM = Efficacy for Pedagogy in Mathematics; ETMC = Efficacy for Teaching Mathematics Content; LMA = Learning Mathematics Anxiety; MEA = Mathematics Evaluation Anxiety; MTP = Mathematics Teaching Philosophy

Discussion

Drawing on the theoretical framework for mathematics identity (Cribbs et al., 2015), the current study explored a measure for mathematics teacher identity. Results of the EFA supported the conceptualisation and operationalisation of the construct as the results aligned with the theorised sub-constructs interest, recognition, and competence/performance. The EFA provided validity and reliability evidence for the use of the mathematics teacher identity measure with K–12 teachers. The variance explained for each of the sub-constructs was similar, with interest being slightly lower at 19% than recognition and competence/performance at 25%. Given that identity involves "managing transactions among internal (e.g., emotions, efficacy) and external (e.g., policy, school structure) elements" (Schutz et al., 2018, p. 5), it is not surprising that each of the three sub-constructs informs a teacher's professional identity.

These findings highlight the importance of a content-specific professional identity measure, similar to the need for content specificity in measuring teacher efficacy (Utley et al., 2005). Hong et al. (2018) noted the importance of this context-specific lens as teachers not only navigate through the broader field of education but also "micro-worlds", which "present ideal views of the identity the [subject] teacher should have, the set of beliefs she should hold, how she should engage with students, and essentially who should be in the classroom" (p. 249). This study adds to the field by contributing a nuanced way to explore teacher identity, allowing for a closer picture of the micro-world in which teachers exist as content experts. Thus, having this instrument for use with in-service teachers provides the potential for future research related to teachers' professional mathematics teaching identity. In addition, this instrument provides a way of exploring the intersections between identity and other constructs as noted by Hannula (2016), as well as intersections between various identity measures that might influence teachers' perceptions of themselves and classroom instruction. Given the role that professional identity has on teacher retention (Hong, 2010) and the current worldwide shortage of teachers (Nguyen et al., 2022; UNESCO, 2022), exploring mathematics teacher identity in conjunction with professional teacher identity measures could provide a more nuanced understanding of teacher attrition and retention. With mathematics teachers having higher levels of attrition than other fields

(Grillo & Kier, 2021), it is possible that a content-specific measure could provide a better understanding of this phenomenon than a general, non-content-specific measure.

Rather than focusing on general teaching philosophy, this single factor mathematics teaching philosophy instrument focuses on specific mathematics practices that research supports as effective practices (NCTM, 2014). Specifically, items that are more student-centered (e.g., learning as an active process) align with what NCTM classified as "productive beliefs" while more teacher-centered practices (e.g., learning as acquisition) are classified as "unproductive beliefs." Thus, the development of this mathematics teaching philosophy allows researchers to explore whether a teacher leans towards a teacher- or student-centered belief system when teaching mathematics. Results from the EFA indicate the mathematics teaching philosophy items are valid and reliable for use with K–12 in-service teachers, with the exclusion of the ninth item related to curriculum. Although other general teaching philosophy measures might provide a picture of a teacher's related beliefs, a discipline-specific measure is important for understanding how these beliefs might differ based on the content being taught. Given that teachers may have different beliefs and identities related to different disciplines, having a discipline-specific teaching philosophy, which aligns with Hannula's (2016) recommendation for content-specific measures, could provide a better picture of these beliefs as it might relate to instruction in the classroom. Schoenfeld (2022) noted the distinct nature of mathematics in making a case for why mathematics as a discipline is difficult to learn and teach. The unique nature of the discipline as well as the reflection of the classroom as a "microcosms of society at large" (p. 31) highlight the need for measures to take into account these discipline-specific elements. The addition of a mathematics teaching philosophy measure provides another tool for researchers and educators to explore the construct.

Further, this study explored the correlations between mathematics identity, mathematical mindset, mathematics teacher identity, self-efficacy towards teaching mathematics, mathematics anxiety, and mathematics teaching philosophy of K–12 in-service teachers. Findings revealed significant correlations among many of the constructs. Specifically, mathematics identity and mathematics teacher identity had a strong positive correlation. While these constructs are distinct, together they can provide a better picture of the multiple identities influencing teachers' behaviours and choices. While prior research noted the connection between teacher identity and burnout (Hong, 2010), future research might provide a more nuanced understanding of how discipline-specific identities might influence teacher burnout or other areas being explored by researchers. Self-efficacy towards teaching mathematics had a moderate positive correlation with mathematics teacher identity. This finding is not unexpected given that the theoretical underpinnings of the sub-construct competence/performance align with self-efficacy.

Mathematics anxiety had a moderate negative correlation with mathematics identity and mathematics teacher identity. Eccles (2009) stated that one of the three components of personal and collective identity is "an efficacy or expectancy component that includes the individual's beliefs about his or her ability to enact these behaviors" (p. 88). This statement highlights the important role that an individual's self-perception as a doer and thinker of mathematics has on the development of their mathematics identity. While prior research found a connection between mathematics anxiety and mathematics identity with undergraduate students (Cribbs et al., 2021b), this study extends that work, noting the important role that mathematics identity plays in the development of teachers' discipline-specific identity. Given the prevalence of mathematics anxiety of elementary teachers (Beilock et al., 2010), this connection poses some concern as to how this anxiety may influence teachers' mathematics identity and subsequent instruction. Other research noted the interplay between mathematics anxiety and professional identity, drawing to attention the importance of "knowledge and skills" on mathematics teacher anxiety (Uygun-Eryurt, 2021, p. 311). Given the connection between these constructs, building teachers' mathematics and professional identities may help reduce teachers' mathematics anxiety or vice versa.

Results also noted weak correlations for several mathematics-specific measures: (1) mathematics identity and teaching philosophy and (2) mathematics anxiety and teaching philosophy. These results are in line with Hadley and Dorward's (2011) study where they found a small positive relationship between elementary in-service teachers' anxiety about mathematics and mathematics instructional practices but no significant relationship between their anxiety about teaching mathematics and their mathematics instructional practices. It is curious that teaching philosophy had the weakest correlations with other constructs. Is it possible that teachers silo some of their beliefs, disconnecting beliefs about their classroom practices from their perceptions of self as a mathematics teacher? Researchers have noted that mathematics teachers can hold different beliefs at the same time (Beswick, 2012). It is also possible that while there is not a direct relationship between mathematics identity and anxiety with teaching philosophy, there might be a mediated relationship. Path modelling might provide additional insight into the connections among constructs.

Limitations and Future Research

A limitation of this study is the focus on one instance of self-reported data, captured at a moment of time using a questionnaire. Of benefit, is the ability to gather data from large samples that generate results that can be replicated and generalised. Although a research strategy that uses questionnaires is an efficient way of collecting data, it does not provide a detailed explanation of the constructs investigated, in this case, teachers' beliefs and identities. This line of research, however, might prove helpful in examining differences based on professional development and/or an intervention with teachers. It might also be used in conjunction with other data to explore how these beliefs and identities might translate to the classroom. While building from qualitative research is essential to understanding better teacher identity and teaching philosophy, quantitative studies can apply these ideas to see how they might translate to different groups of teachers, across time, and in various contexts. The instruments developed in this study provide a method for exploring these various avenues of research. To enhance understanding of the complex nature of identity development, this research illustrates how other identity measures can be explored in conjunction with general professional identity. Additionally, future research can delve deeper into the mathematics beliefs investigated in this study to examine potential differences between elementary and secondary teachers.

Ethics Declarations

Ethical approval

Ethical approval for the research was granted by the Institutional Review Board at Oklahoma State University and informed consent was given by all participants for their data to be published.

Competing interests

The authors declare there are no competing interests.

Corresponding author

Jennifer Cribbs, PhD
School of Teaching, Learning & Educational Sciences
Oklahoma State University
Stillwater, Oklahoma
United States
jennifer.cribbs@okstate.edu

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Appendix A: Mathematics Teacher Identity

To what extent do you agree or disagree with the following statements?

Statements	Strongly Disagree	Disagree	Neither agree nor Disagree	Agree	Strongly Disagree
1. I can see myself as a math teacher.	1	2	3	4	5
2. My family sees me as good at teaching math.	1	2	3	4	5
3. My friends/colleagues see me as good at teaching math.	1	2	3	4	5
4. Others ask me for help in math.	1	2	3	4	5
5. I enjoy teaching others math.	1	2	3	4	5
6. Thinking about ways to teach math topics is fun.	1	2	3	4	5
7. It is interesting to observe/listen to others develop their thinking in math.	1	2	3	4	5
8. I am passionate about sharing ideas in math with others.	1	2	3	4	5
9. I know the steps necessary to teach math concepts effectively.	1	2	3	4	5
10. I am confident I can teach math well.	1	2	3	4	5
11. I understand math concepts well enough to be effective when teaching them.	1	2	3	4	5
12. When a student has difficulty understanding a math concept, I usually know how to help the student understand it better.	1	2	3	4	5
13. I know how to turn students on to math.	1	2	3	4	5

Appendix B: Mathematics Teaching Philosophy

Indicate where on the continuum you believe best reflects your current beliefs regarding each pair of statements.

1	Teacher is the sole authority source of knowledge. Knowledge is transmitted from teacher to student (teaching is telling).	1	2	3	4	5	Teacher challenges and guides student teaching toward understanding. Knowledge is subjective and students construct their own knowledge through interactions with others and reflecting upon their experiences.
2	Students lack knowledge and need teacher assistance in learning.	1	2	3	4	5	Students are capable of creating their own understanding and managing their own learning.
3	Learning is about acquisition of facts, skills, and concepts and typically occurs through drill and practice in isolation.	1	2	3	4	5	Learning is an active process where knowledge is socially constructed, connecting to our prior knowledge and occurs through context.
4	All classroom interactions are initiated by the teacher (teacher-student).	1	2	3	4	5	Classroom interactions involve a combination of student-student, teacher-student, and student-teacher interactions throughout the lesson.
5	Assessment of mathematical understanding is obtained through "objective" pencil and paper tests.	1	2	3	4	5	Assessment of mathematical understanding is obtained through a variety of assessment strategies including both formative and summative assessment.
6	Assessment is primarily focused on accountability (e.g. report cards, grades, etc.).	1	2	3	4	5	Assessment is primarily focused on improving student understanding.
7	Teacher expects students to work individually. Students are typically arranged in rows facing the front of the classroom.	1	2	3	4	5	Teacher encourages collaboration. Students are typically arranged to enable students to easily collaborate.
8	Teacher initiates activities. Student input is acknowledged but not expected.	1	2	3	4	5	Teacher focuses on student questions as an instructional goal.