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ORIGINAL ARTICLE

Mathematics identity instrument development for fifth through twelfth grade students

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Abstract

Given the importance of mathematics identity for students continued participation and engagement with mathematics, it is important for educators and researchers to be able to explore students' mathematics identity development. However, an instrument with validity evidence that can be used to explore mathematics identity efficiently and with groups of students is not currently available. This article draws on prior research to test and validate items for a mathematics identity instrument to be used with fifth through twelfth grade students. This study includes 1559 participants from two school districts in a midwestern state in the USA. Analysis includes assessing four components of validity including content validity, internal structure, relationship to other variables, and generalization. Findings provide evidence for the reliability and validity of the items in the mathematics identity scale, giving researchers and educators a way to explore this construct efficiently.

Keywords Mathematics identity · Middle grades · High school · Factor analysis

Research has increasingly highlighted the importance of mathematics identity on students' future goals and academic outcomes. For example, in a longitudinal study with high school students conducted by Bohrnstedt et al. (2021), mathematics identity was found to be positively correlated with mathematics achievement. Other research (e.g., Cribbs et al., 2016, 2020; Godwin et al., 2016) has repeatedly shown that mathematics identity is a strong predictor for students' career choice in a variety of STEM fields, such as engineering, mathematics, and science. Given how strongly mathematics identity connects to these student outcomes, developing a measure

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to use with middle grades and high school students could provide educators and researchers with an efficient method of exploring mathematics identity in school or informal classroom settings. 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 generalization of findings (Kelle & Buchholtz, 2015)" (p. 513). This is also the case for research on learner identity, where researchers could extend work in the field by using both qualitative and quantitative approaches. Additionally, having a measure for learner identity could be used to explore connections between learner and teacher identity. However, an instrument with validity evidence is not yet available for researchers to use for these purposes. The few quantitative studies on the topic have either used items from the NAEP (National Assessment of Educational Progress) data or researcher-designed assessment items, neither with validity or reliability evidence for the measure being reported (Bohrnstedt et al., 2020, 2021; Ingels et al., 2011; Lesko & Corpus, 2006). There is an existing mathematics identity measure that has validity and reliability evidence, but these items were developed for and have been validated with undergraduate students enrolled in single-variable calculus (Cribbs et al., 2015).

Given the employment needs in STEM areas, the focus on persistence in STEM careers such as in computer and mathematical science is important and is projected to be one of the fastest growing fields in the USA from 2021 to 2031 (U.S. Bureau of Labor Statistics, 2022). Other countries are seeing similar demands for STEM workers, with the Department of Employment, Skills, Small and Family Business (2019) predicting significant employment growth for professionals, particularly with software and applications programmers. Likewise, it is anticipated that Europe will have seven million STEM job openings by 2025 (Women in Aerospace Europe, 2021). Along with the financial opportunities provided to individuals pursuing these fields, developing a strong mathematics identity is important for students' daily lives. Organizations such as the National Council of Teachers of Mathematics (NCTM) have made this point evident, stating, "those who understand and can do mathematics will have significantly enhanced opportunities and options for shaping their futures" (NCTM, 2000, p. 5). NCTM's increased focus of mathematics identity development for K-12 students was also made evident in a position statement noting that "the NCTM Board has officially reframed its enquiry work to focus on Access, Equity and Empowerment to capture the critical constructs of students' mathematical identities, sense of agency, and social justice" (Larson, 2016, para. 5). This focus was further supported in the Catalyzing Change series (NCTM, 2018a, b, c), which highlights the essential role of mathematics identity and mathematical agency on students learning. Additionally, the new NCTM accreditation standards for the preparation of secondary mathematics teachers requires evidence from teacher candidates that demonstrates they understand a teacher's impact on students' mathematical identities and can plan instruction to support positive identity development (NCTM, 2020). The increased focus on developing productive mathematics identities for K-12 students is a byproduct of decades of research noting that how students view themselves as a "mathematics person" has a significant role on their participation and future engagement with mathematics (Boaler & Greeno, 2000; Boaler &

Selling, 2017). In addition, research notes that what occurs in the classroom can influence students' mathematics identity development (Cribbs et al., 2020; Bishop, 2012; Cobb et al., 2009).

An instrument with supporting validity and reliability evidence could provide an efficient method of exploring mathematics identity in informal and formal settings for educators and researchers. In addition, in a review of research on learner mathematics identity, Radovic et al. (2018) noted the relatively limited number of studies exploring identity with middle school students ($n=8$, 12%) in comparison to other areas of research. However, research notes the importance of this stage in students' schooling, finding the largest drop in students' attitude and interest toward mathematics (Harter, 1981; Marsh, 1989) as well as the predictive nature of students' career goals to them ultimately complete a STEM degree (Maltese & Tai, 2011). With evidence of other affective measures for mathematics declining over this period of students schooling, we might anticipate a similar decline in identity as well. Given the importance of mathematics identity as well as the pivotal time the middle grades are to students schooling, having a validated instrument to use by the field would provide opportunities to assess students' mathematics identity over this time, particularly to align potential interventions or to test programs and interventions being used in these settings. Currently, there are limited validated measures for mathematics identity. The few quantitative measures available in the field either do not provide validity evidence or were validated with a different population. For example, Bohrnstedt et al. (2020, 2021) used a measure for mathematics identity, but provided no supporting validity evidence for this measure. Kaspersen and Ytterhaug (2020) created a measure for mathematics identity with supporting validity evidence. However, this study used a different framework for their study (personal mathematics identity), and did not include the same population, starting with 8th graders, and was conducted in Norway. Calls from the field note a need to make transparent validity evidence associated with measures being used and/or developed (Bostic et al., 2019a, b). Furthermore, Graven and Heyd-Metzuyanim (2019) indicated that all but two studies in their review of literature on mathematics learner identity had eight or less participants, noting a gap in the literature with larger sample sizes. The current study proposes to fill these gaps in the literature through the development of a mathematics identity instrument for 5th–12th grade students.

Theoretical framework

The ways in which mathematics identity is defined and operationalized in prior research differ greatly and depend on the perspectives and approaches of the researchers conducting the studies (Cribbs et al., 2020; Darragh, 2016; Graven & Heyd-Metzuyanim, 2019; Radovic et al., 2018). For instance, researchers have framed their work based on figured worlds (Holland & Lave, 2001), discourse (Sfard & Prusak, 2005), and social factors, such as race (Larnell, 2016; Martin, 2000, 2006). These different settings and ways of conceptualizing the construct are not mutually exclusive, but often overlap (Bishop, 2012), as seems inevitable when investigating a complex concept in what is often a messy and dynamic environment,

such as the classroom. These varied perspectives provide nuanced pictures of students' mathematics identity, but not necessarily the entire picture of students' identity development as this would be informed by the specific approach taken. In addition to providing a way to understand how and why students position themselves in the classroom in certain ways, the concept of mathematics identity helps us better understand why students may or may not want to pursue mathematics (Cribbs et al., 2020; Boaler & Greeno, 2000).

For the purpose of our work, we are situated explicitly within the theoretical perspective of core identity (Cobb & Hodge, 2011; Gee, 2001). Core identity reflects an individual's more enduring sense of identity. Drawing from this perspective, identity is viewed as a "thickening" process as described by Holland and Lave (2001), "The person is necessarily 'spread' over the social environment, becoming in substance a collection point of socially situated and culturally interpreted experiences. And herein lie important sources of stability and thickening" (p. 19). Through this perspective, it is anticipated that individuals accumulate experiences that inform how they see themselves and that over time this sense of self becomes more stable. Aligned to this perspective, we define mathematics identity as how individuals see themselves in relation to mathematics, based upon their perceptions and navigation of everyday experiences with mathematics (Enyedy et al., 2006). This definition captures an essential aspect of examining identity as a self-perception. As Boaler and Greeno (2000) stated that "what happens in mathematics classrooms matters less within representations of figured worlds than the teachers' and students' perceptions of what happens" (p. 189). Their statement highlights the importance of capturing students' perceptions about their own identity. In addition, our definition captures the significance of everyday, accumulating experiences in informing an individuals' mathematics identity development, which aligns to conceptualizing identity as a process of *thickening* over time.

In terms of how mathematics identity is operationalized, we draw on the theoretical underpinnings of core identity. From this perspective, we explore how identity influences individuals' long-term engagement and decisions related to mathematics. For example, Carlone and Johnson (2007) noted that there were particular aspects that contributed to women of color's science identity as they transitioned through college into science-related careers, finding three constructs which were important to their participants science identity development: recognition, competence, and performance. However, Hazari and her colleagues (2010) endeavored to draw on Carlone and Johnson's (2007) work as well as Social Cognitive Career Theory (e.g., Bandura, 1997; Lent et al., 1994, 1996) to examine physics identity as a measure of persistence in the field. In shifting this perspective, interest was added as a fourth component of identity development. It is from these studies as well as prior studies in mathematics identity (Cribbs et al., 2015) that we developed the four sub-factors of mathematics identity. Other work also supports the inclusion of these factors for mathematics identity. For example, when asking undergraduate students what it means to be a "math person," the highest percentage of responses indicated they view mathematics identity to be connected to interest, competence, and performance (Cribbs et al., 2022). In addition, that study found that students who lacked recognition by their teachers in particular self-reported a

lower mean for mathematics identity, highlighting the important role of recognition (Cribbs et al., 2022). Reflecting on how we define mathematics identity, the four sub-factors provide a picture of the perceptions individuals are reflecting on when considering what it means to be a "math person." Additionally, individuals reflecting on their experiences are able to provide examples of how the experiences have informed their identity (Cribbs et al., 2022). Prior work using a similar framework (Cribbs et al., 2016, 2020; Godwin et al., 2016) provides evidence that the measure is aligned to the core identity framework and can be used as a way of exploring student persistence or engagement in the field. Other identity work notes the powerful role of identity, finding that identity mediates between other affective measures (e.g., mathematics mindset, mathematics anxiety, self-efficacy) and student outcomes (e.g., career interest, achievement; Cribbs et al., 2020; Bohrnstedt et al., 2020; Stets et al., 2017). These four factors (interest, recognition, competence, and performance) serve as sub-constructs of the mathematics identity scale, and together provide a picture of an individual's sense of self as it relates to the content.

Additionally, it is important to understand how each of these sub-constructs is defined and situated within prior research. First, interest is defined as a student's desire or curiosity to think about and learn mathematics. Research has noted the importance of interest on students' attention (Harackiewicz, et. al., 2016), academic motivation (Ainley, 1998), career choice (Lent et al., 2008; Renninger & Hidi, 2016; Su et al., 2009), and identity (Mangu et al., 2015; Renninger, 2009). Next, recognition is defined as how students view themselves and how they perceive others to view them in relation to mathematics. This sub-construct is consistent with how other researchers have discussed mathematics identity indicating that "It [mathematics identity] also encompasses how others 'construct' us in relation to mathematics" (Martin, 2006, p. 2006). Expressing whether or not they are a *math person* is a commonly used expression individuals use to discuss their own sense of identity. Wang and Hazari (2018) found that the ways teachers used explicit and implicit recognizing strategies in the classroom influenced high school students' physics identity. Students recognizing themselves as "good at mathematics" is also important to student mathematics identity development (Darragh, 2015). Parents also inform how students see themselves, with research noting the parents' mathematics anxiety and beliefs about mathematics influences their children's mathematics attitudes (Gunderson et al., 2012). Other research also supports the importance of recognition finding it was a stronger predictor of mathematics identity than interest or competence/performance (Cribbs et al., 2015). Lastly, competence is defined as students' beliefs about their ability to understand mathematics, and performance is defined as their beliefs about their ability to perform in mathematics. Both competence and performance are linked to self-efficacy (Bandura, 1997), which prior research has shown to be linked to one's identity (Hazari et al., 2010).

Prior research with this framework found that competence and performance load together (Cass et al., 2011). While items for measuring mathematics identity using this framework have been validated with undergraduate students (Cribbs et al., 2015), they have not been validated with K-12 students. Additionally, much research in this area has taken a narrative approach (Radovic et al., 2018; Hernandez-Martinez et al., 2011), focused on a small group of participants (Smith, 2010), or has used a measure

that has no validity or reliability evidence provided (Bohrnstedt et al., 2020, 2021; Ingels et al., 2011). Thus, the current research project is focused on validating items to measure 5th–12th grade students' mathematics identity. The research question for this study is: What are the psychometric properties for the Mathematics Identity scale for grades 5–12?

Methods

This study employed a survey design, collecting data with a large sample ($N = 1559$) of 5th–12th grade students at one point in time. The survey included items related to student demographics (e.g., age, grade level), two open-ended items related to mathematics identity (not analyzed as part of the current paper), and questions for seven different constructs (e.g., mathematics identity, mathematics anxiety).

Development of mathematics identity instrument

The development of the mathematics identity instrument was guided by the *Standards for Educational and Psychological Measurement in Education* (AERA, APA, & NCME, 2014) and associated literature in mathematics education (Bostic et al., 2019a), which provide clear guidelines for how researchers can provide validity and reliability evidence for instrument development. In drafting items for the mathematics identity scale, prior items validated for use with undergraduate students were used (Cribbs et al., 2015). That instrument consisted of 11 items using a Likert scale (1: strongly disagree; 5: strongly agree) and was composed of the three sub-constructs of mathematics identity (interest, recognition, and competence/performance) as detailed in the theoretical framework. However, it was important to establish validity and reliability evidence for the population of interest. For example, it is anticipated that children and adults might have differing reading levels, so it was important to assess the readability and clarity of items developed for 5th–12th grade students. There had also been considerable time since the last instrument was developed, so a review of mathematics identity literature (e.g., Aguirre et al., 2013; Bishop, 2012; Darragh & Radovic, 2018) was an important step when considering drafting additional or revised items for the scale. The additional items considered for the scale were intended to capture other potential sources of recognition, adding an item related to recognition from friends to the measure given the role that peer groups play in adolescents' perceptions (Schunk & Meece, 2006). In addition, with the prior instrument, competence and performance loaded as one factor (Cass et al., 2011). However, we wanted to consider these constructs individually in our study rather than assume they loaded together for this population as prior qualitative work distinguishes between the constructs (Carlone & Johnson, 2007). For this reason, we added additional competence and performance items to be sure they would have at least 3 items needed to determine if they would load as separate factors with our target sample. The next steps in the instrument development process are summarized in Table 1 and described in more detail in the data analysis section. There are four

Table 1 Summary of validity evidence in the current study

Form of validity	Evidence
Content validity	• Expert panel content review • Readability analysis
Internal structure	• Correlation analysis • Exploratory factor analysis • Confirmatory factor analysis
Relationship to other variables	• Correlation test
Generalization	• Internal consistency

sources of validity addressed in this study (content validity, internal structure, relationship to other variables, and generalization) aligned to the guidelines provided in the literature (AERA, APA, & NCME, 2014; Bostic et al., 2019a). Each source of validity includes one or more components of evidence.

Measure used for validity evidence

As part of validity evidence in this study, mathematics anxiety was used as evidence of a relationship between mathematics identity and a related construct. Given that both mathematics identity and mathematics anxiety are predictive of similar outcomes (e.g., mathematics achievement; Bohrnstedt et al., 2021; Donolato et al., 2020) and correlated with similar constructs (e.g., self-efficacy; Bohrnstedt et al., 2020; Huang et al., 2019), it is not surprising to find that these constructs are also correlated with each other. This relationship has previously been established, with one study finding that students' mathematics anxiety was predictive of their mathematics identity (Cribbs et al., 2021). That study also found mathematics identity was a full mediator for mathematics anxiety in predicting student's STEM career interest. Literature notes the potential connection between domain-specific anxiety or stress and identity threat, indicating that self-perceptions in mathematics related to the level of mathematics-specific stress students reported (Ramirez et al., 2017).

The modified Abbreviated Math Anxiety Scale (mAMAS; Carey et al., 2017) is a self-report 5-point Likert-type scale ranging from 1 (low anxiety) to 5 (high anxiety) indicating how anxious they felt during a variety of situations. The mAMAS consists of nine items on two subscales: Learning Math Anxiety (LMA; 5 items) and Mathematics Evaluation Anxiety (MEA; 4 items). Illustrative items are *Starting a new topic in math* (LMA) and *Taking a math test* (MEA). Using a Cronbach alpha analysis, Carey and colleagues (2017) found good internal consistency for the scale overall (0.85), Learning Math Anxiety subscale (0.77), and Mathematics Evaluation Anxiety subscale (0.79).

Participants and data collection

Researchers collaborated with educators in two large school districts to collect data for this study, which occurred in the spring semester of 2022. These two districts were chosen based on student demographics and prior relationships

researchers had with these districts. One suburban district had demographics representative of the overall student demographics for the state, while the second large district was located in a rural area with a higher Native American student population than the overall state demographics. Students in 5th and 6th grades in one district completed a paper version of the survey, while all other students in both districts completed an online survey via Qualtrics. The survey was administered in either the students' advisory (non-content-based class for student advising purposes) or mathematics class. Teachers handed out the survey or provided students with the survey link, read a script prepared by the research team to students, provided students with an opportunity to review an assent form, and provided time in the class for students to complete the survey. Paper surveys were collected by a district contact, which was later collected by a research team member. A total of 1655 completed surveys were received. After reviewing the data set and removing anomalous responses (e.g., participants who answered all Likert-type questions the same) and participants missing a substantial number of responses (e.g., no responses on Likert-type questions), the sample size was 1559. In order to conduct the necessary analysis in this study, the sample was split. This process involved grouping participants by grade level, then gender, and then race to ensure representation across both samples. At that point, every other participant was pulled to be added to a separate dataset. Table 2 provides an overview of the sample size and demographic information for both of these datasets providing evidence of similar demographics across the two datasets.

Table 2 Summary demographic for EFA and CFA samples

	EFA	CFA		EFA	CFA
N	780	779	Race		
Gender			White (%)	55.4	55.7
Male (%)	47.2	44.0	Native American and White (%)	17.1	16.8
Female (%)	50.0	53.6	American Indian/Native American (%)	7.6	7.2
Other (%)	1.8	1.7	Multicultural (%)	5.7	6.0
Not specified (%)	1.0	1.7	Uncertain (%)	5.3	5.3
Age range	10–19	9–18	Black/African American (%)	3.7	3.3
Grade level			African American and White (%)	2.6	2.6
5th (%)	17.2	17.2	Asian (%)	2.4	2.6
6th (%)	12.7	12.8	Other (%)	0.6	0.9
7th (%)	10.3	10.3	Hispanic (% Yes)	20.3	19.1
8th (%)	11.2	11.0			
9th (%)	11.5	11.7			
10th (%)	20.6	20.5			
11th (%)	10.9	10.9			
12th (%)	5.5	5.5			

Data analysis

In order to evaluate the psychometric properties of the Mathematics Identity scale for 5th–12th grade students, analysis aligned to each associated form of validity as shown in Table 1 was conducted. The three identity experts provided qualitative feedback on the instrument. The readability analysis was conducted through informal interviews with four children (one for each grade level from 5 to 8th grade) as they completed the survey, and a readability analysis was done using by calculating the Flesch reading ease and Flesch-Kincaid grade level indicator (Kincaid et al., 1975). All other analyses were conducted using R statistical software package (version 4.1.2).

After determining that the missing data was missing completely at random, simple random imputation (also known as hot deck imputation) was performed, which is a better alternative to listwise or mean imputation (Schlomer et al., 2010) and is appropriate for relatively large sample sizes with less than 20% missing responses (Stavseth et al., 2019). The current dataset has a sufficiently large sample size and less than 2% missing responses for all variables included in the study, making simple random imputation suitable. Exploratory factor analysis (EFA) was used to explore the internal structure of instrument items. Promax rotation was used for both EFA as it is theorized that the items are correlated. Analysis also included calculating overall correlations between items, Kaiser–Meyer–Olkin measure, Bartlett's test of sphericity, item-total correlations, and parallel analysis (Horn, 1965). Confirmatory factor analysis (CFA) was performed using the final model from the EFA. Drawing from literature, the following fit indices were reported in this study with recommended threshold levels noted in parentheses: (a) NNFI (>0.90), (b) CFI (>0.90), (c) RMSEA (<0.08), and (d) SRMR (<0.05) (Awang, 2015; Schumacker & Lomax, 2016).

A correlation test was conducted between the mathematics identity construct (based on final items from the EFA and CFA) and mathematics anxiety to provide evidence of a relationship between these variables as noted in prior research (Cass et al., 2011). Finally, internal consistency was reported for the overall mathematics identity measure as well as the sub-constructs using Cronbach's alpha.

Results

Validity evidence from scale content

Expert panel content review

The expert panel consisting of four experts in the area of identity was asked to provide substantive feedback on instrument items developed for the measure. A brief summary of the mathematics identity framework was also provided to aid the experts prior to reviewing the items, with the prompt: *Does the proposed Math Identity questionnaire align with the math identity framework provided? Please provide us with issues/concerns that we should consider along with constructive ways we*

might address those concerns. In reviewing the instrument items, the panel was asked to examine.

(a) The wording of each question for clarity and appropriateness for students,
(b) Whether each question accurately reflects the proposed sub-construct as laid out in the framework, and
(c) For each sub-construct the set of questions as a whole and whether they capture the sub-construct or whether additional items are needed

Some suggestions were made regarding how items were worded, such as using "satisfaction" rather than "fulfillment," which might be a term in which students are familiar. We also removed a negatively worded item and some additional items that were redundant, reducing the number of items from 22 to 18.

Readability

Prior to the administration of the mathematics identity scale in this study, four students in grades 5, 6, 7, and 8 ranging from below-average to above-average reading abilities were asked to read and complete the mathematics identity scale. During this process, readers voiced ideas about their mathematics identity, which matched their responses on the items. Students did not have issues or concerns regarding the 18 items in the mathematics identity measure, so all items were retained without any additional revisions to the wording. Additionally, the Flesch reading ease and Flesch-Kincaid grade level indicator (Kincaid et al., 1975) were calculated. The Flesch-Kincaid grade level was 3.0. This suggests that students in the third grade or above could read the mathematics identity scale items with ease. Additionally, the Flesch reading ease score of 86.0 suggests that the material was easy to read for fifth graders and above.

Validity evidence from internal structure

Exploratory factor analysis

In order to examine the internal structure of the construct, correlations were calculated between all the variables in the measure. According to Field et al. (2012), correlations below 0.3, as would be expected if measuring the same construct, and greater than 0.8, to avoid potential multicollinearity, should be considered for possible exclusion. As shown in Table 3, there were no correlations less than 0.3. There were three correlations greater than 0.8. Two of these occurrences were between interest items with correlations of 0.83 and 0.81. Given that these correlations were close to 0.8, that reducing the number of items in the sub-construct below four is not ideal for subsequent analysis, and that the questions were distinct, the decision was made to keep these items. The third high correlation was between two recognition items. After reviewing the questions and considering the high correlation at 0.85, the decision was made to remove MR 4, reducing the number of items in the

Table 3 Correlations between mathematics identity variables

	MI 1	MI 2	MI 3	MI 4	MR 1	MR 2	MR 3	MR 4	MR 5	MC 1	MC 2	MC 3	MC 4	MC 5	MC 6	MC 7	MC 8	MC 9
MI 1	1																	
MI 2	.83	1																
MI 3	.81	.79	1															
MI 4	.76	.75	.77	1														
MR 1	.68	.67	.72	.74	1													
MR 2	.55	.54	.59	.58	.70	1												
MR 3	.54	.55	.58	.61	.71	.68	1											
MR 4	.58	.58	.58	.59	.73	.72	.85	1										
MR 5	.56	.56	.55	.56	.63	.65	.70	.70	1									
MC1	.56	.56	.54	.50	.52	.45	.48	.47	.48	1								
MC 2	.59	.59	.60	.57	.58	.48	.52	.52	.53	.75	1							
MC 3	.50	.50	.53	.53	.52	.43	.47	.44	.43	.64	.74	1						
MC 4	.50	.50	.47	.49	.52	.49	.59	.58	.50	.47	.50	.49	1					
MC 5	.53	.53	.52	.50	.54	.47	.53	.52	.53	.66	.68	.58	.54	1				
MC 6	.55	.55	.50	.50	.50	.46	.51	.48	.51	.60	.67	.58	.55	.68	1			
MC 7	.64	.64	.63	.60	.62	.53	.61	.59	.59	.71	.75	.67	.59	.71	.70	1		
MC 8	.53	.53	.50	.49	.51	.46	.50	.51	.54	.63	.66	.54	.53	.72	.61	.71	1	
MC 9	.60	.60	.63	.60	.66	.57	.59	.59	.56	.64	.71	.66	.54	.68	.63	.77	.65	1

MI mathematics interest, *MR* mathematics recognition, *MC* mathematics competence/performance

sub-construct from five to four. Item-total correlations were also calculated, ranging from 0.64 to 0.83. Additionally, dropping one of the items from the survey did not increase the Cronbach alpha, indicating that no additional items should be dropped based on this analysis.

An EFA was also conducted using promax rotation, as sub-constructs were hypothesized to be correlated. The sample size of 780 was more than adequate given the recommendation of 10 to 15 participants per variable (Field et al., 2012). This guideline would indicate that a minimum sample size of 180 was needed to conduct the desired analysis. Additionally, a sample size of 500 or greater is considered very good for conducting factor analysis (Comrey & Lee, 2013). Prior to running the EFA, sampling adequacy was examined through the Kaiser–Meyer–Olkin measure, which was 0.96, with individual items at 0.88 to 0.97, well above the recommended 0.5 and considered "marvelous" at or above 0.9 (Kaiser, 1974). Additionally, Barlett's test of sphericity was significant (χ^2 (120) = 11,326, $p < 0.001$), indicating that the items are acceptable for conducting the EFA. A Scree plot (see Fig. 1) and parallel analysis determined that three factors should be retained.

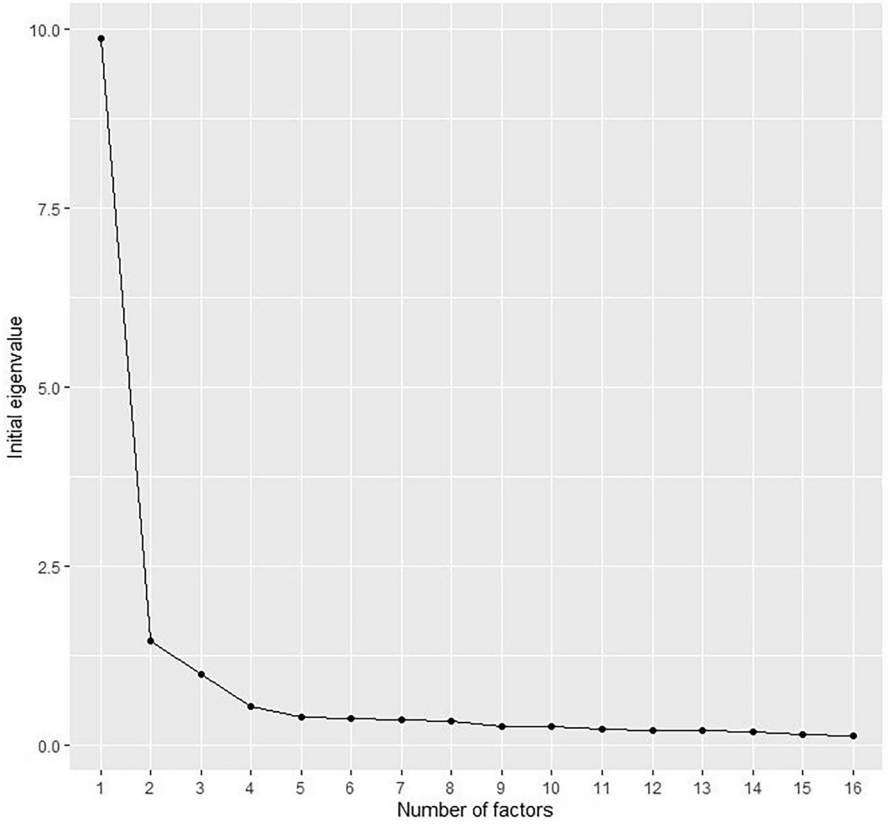


Fig. 1 Scree plot for mathematics identity

Results of the EFA also support the inclusion of three factors, reported in Table 4. One item was removed due to crossloading and a low loading score of 0.38 on the factor it was intended to load onto (excluded from Table 4). After removing this item, 16 items are included on the scale, with fit indices within recommended levels (Schumacker & Lomax, 2016) and items having a loading score of 0.56 or greater. Additionally, items loaded as theorized on the three sub-constructs (interest, recognition, and competence/performance). The sub-construct interest had the largest percentage of variance explained at 33%, while recognition and competence/performance explained 21% and 17% of the variance. The three factors explained 71% of the cumulative variance.

Confirmatory factor analysis

CFA was conducted with maximum likelihood estimation. Results indicated that all items were significant ($p < 0.001$) and variables loading as expected. Results of the CFA are shown in Table 5 along with the standardized factor loadings, item reliability for indicator variables, fit indices, and construct reliability and average variance extracted from latent variables. Factor loadings were greater than 0.4, ranging from 0.70 to 0.92. Fit indices provided evidence of a good fit model, χ^2 (97) = 399.736, $p < 0.001$, TLI = 0.96, CFI = 0.97, RMESA = 0.063, C.I. = 0.057–0.070, SRMR = 0.028. Item reliability (R^2) ranged from 0.48 to 0.84. Chi-square is often significant for large sample sizes (Schumacker & Lomax, 2016); therefore, other fit indices are used to assess the model. Convergent validity (level of confidence that the construct is measured by the variables) was also calculated for each of the factors in the CFA analysis using Average Variance Extracted (AVE). The AVE for the interest, recognition, and competence/performance subscales were 0.74, 0.65, and 0.60, respectively, greater than the acceptable value of 0.5 (Alarcón & Sánchez, 2015). Correlations across items were 0.3 or greater as would be expected. Overall, the CFA results provide evidence of a good fit model based on the three mathematics identity subscales.

Validity evidence from relationships to other variables

First, the internal consistency was calculated for this administration of the mathematics anxiety scale which resulted in Cronbach's alpha of 0.88 for the overall scale, 0.80 for the LMA subscale, and 0.88 for the MEA subscale. Then, a correlation test was conducted between mathematics identity and mathematics anxiety using Pearson's correlation coefficient. Results of the correlation test indicated a significantly negative relationship between the constructs with $r = -0.36$, $p < 0.001$. This finding is consistent with prior research noting a negative relationship between mathematics identity and mathematics anxiety (Cribbs et al., 2021).

Internal consistency

A measure of internal consistency for the EFA sample was calculated for the Mathematics Identity scale and each of its subscales. For the overall scale, the internal consistency using Cronbach's alpha for the overall scale was 0.96. The internal

Table 4 EFA results for mathematics identity ($N = 780$)

Latent variable		Survey item	Factor 1 loading	Factor 2 loading	Factor 3 loading
Interest (%VE = 33)		I enjoy learning math	.88		
		Math is interesting	.88		
		I look forward to taking math	.84		
		I find satisfaction in doing math	.73		
Recognition (%VE = 21)		I see myself as a math person		.56	
		My family sees me as a math person		.79	
		My classmates see me as a math person		.87	
		My teacher sees me as a math person		.70	
Competence/performance (%VE = 17)		I understand the math I have studied			.84
		I feel confident that I can understand math in school			.88
		I feel confident that I can understand math outside of school			.73
		I can do well on math tests			.83
		I can overcome setbacks in math			.73
		I am good at solving math problems			.76
		I can get good grades in math			.76
		Doing math is easy for me			.63
Index		Actual	Recommended		
RMSR	.02		< .05		
RMSEA	.07		.05 to .08		
TLI	.96		> .95		

VE variance explained, *RMSR* root mean square residuals, *RMSEA* root mean square error of approximation, *TLI* Tucker-Lewis index

Table 5 CFA results for mathematics identity ($N = 779$)

Latent variable	Survey item	Std. loading	Item rel	Fact. rel	Avg. var. ext
Interest	I enjoy learning math	.92	.84	.93	.74
	Math is interesting	.88	.77		
	I look forward to taking math	.88	.78		
	I find satisfaction in doing math	.82	.67		
Recognition	I see myself as a math person	.89	.78	.89	.63
	My family sees me as a math person	.78	.61		
	My classmates see me as a math person	.78	.61		
	My teacher sees me as a math person	.85	.73		
Competence/performance	I understand the math I have studied	.75	.56	.93	.61
	I feel confident that I can understand math in school	.81	.66		
	I feel confident that I can understand math outside of school	.70	.49		
	I can do well on math tests	.78	.61		
	I can overcome setbacks in math	.71	.50		
	I am good at solving math problems	.86	.74		
	I can get good grades in math	.76	.58		
	Doing math is easy for me	.81	.66		
Model $\chi^2 = 399.74$	$Df = 97$				
Null Model $\chi^2 = 10{,}036.45$	$Df = 120$				
TLI = 0.96					
CFI = 0.96					
RMSEA = 0.063	C.I. = 0.57–0.70				
SRMR = 0.028					

TLI Tucker-Lewis fit index, *CFI* comparative fit index, *RMSEA* root mean square error of approximation, *SRMR* standardized root mean square residual, *CI* confidence interval, *DF* degrees of freedom

consistency was 0.94 for the interest subscale, 0.89 for the recognition subscale, and 0.94 for the competence/performance subscale.

Discussion

Prior research has shown that mathematics identity plays an important role in students' career choice (Cribbs et al., 2016, 2020; Boaler & Greeno, 2000; Godwin et al., 2016), outcomes such as mathematics achievement (Bohrnstedt et al., 2021), and how students choose to engage with each other and the content in mathematics classrooms (Bishop, 2012; Esmonde & Langer-Osuna, 2013; Langer-Osuna, 2017). Evidence from other research notes that mathematics identity has more predictive power on students' mathematics achievement than other measures (math self-efficacy and math interest) (Bohrnstedt et al., 2020). A major contribution of this study is that it fills a gap in the literature. While there is an instrument to measure undergraduate students' mathematics identity (Cribbs et al., 2015), we were unable to locate a validated and published mathematics identity measure for use with students in grades 5–12. With the increased focus of mathematics identity as a topic of study as well as calls, standards, and initiatives aligned to this focus, a measure to assess and explore mathematics identity with children will benefit the field. This measure takes a unique approach for how mathematics identity is explored, and with the inclusion of recognition in the scale, the measure provides a unique perspective of student perceptions that is not currently included in other measures (e.g., attitudes, beliefs). Hence, we are hopeful that this measure provides a tool for researchers to explore the perceived mathematics identity of grades 5–12 students.

As Bostic and Sondergeld (2015) point out, it is critical for mathematics education researchers to have "confidence that results from mathematics measures are consistently measuring (reliability evidence) what we expect them to measure (validity evidence)" (p. 289). Results of this study provide validity evidence for the proposed mathematics identity measure in four forms: content, internal structure, relationship to other variables, and generalization. Collectively, these four forms of validity evidence provide converging evidence of adequate psychometric properties for the 16-item Mathematics Identity scale and that the scale is aligned to the theoretical framework. Additionally, the readability analysis revealed the mathematics identity scale is appropriate for use with 5th–12th grade students. To further advance research related to mathematics identity, it is important to have the ability to not only analyze grades 5–12 mathematics identity using qualitative methods (e.g., interviews) but also through quantitative methods (e.g., mathematics identity scale).

Results of this study align with results for the mathematics identity measure used with undergraduate students (Cribbs et al., 2015). Despite designing items on the measure to consider competence and performance separately, these constructs loaded as one factor, which is consistent with the previous study conducted with undergraduate students. One explanation for this result could be that students compartmentalize these concepts, seeing competence and performance in mathematics as synonymous. The current study results are consistent with the conceptual identity framework from prior identity research with undergraduate students (Cribbs et al.,

2015, Godwin et al., 2016; Hazari et al., 2010). One finding of note is the amount of variance explained from the three sub-factors of mathematics identity. In previous research with undergraduate students, interest accounted for the smallest percentage of cumulative variance explained (18%) and competence performance the largest (44%; Cass et al., 2011). However, this is the reverse for the current study with interest at 33% and competence/performance at 17%. This might be evidence that there is a shifting in what is informing students' mathematics identity over time based on the various mathematical experiences accumulated. Better understanding how these sub-factors of mathematic identity are informing students' overall mathematics identity might inform researchers and educators as they develop methods for supporting students' identity development in classrooms, such as the model for supporting mathematics identity proposed by Gresalfi and Hand (2019) or accreditation standards for teacher practice (NCTM, 2020).

Limitations and suggestions for future research

It is important to note that there are some limitations to this study to keep in mind when using the measure. First, while the sample was strategically collected across grade levels and with consideration to demographics, the sample size is not necessarily generalizable across all demographics and regions. For example, the sample includes a proportionally small percentage of Black/African American students. As noted by prior research, social and classroom norms as well as racial identity inform how students see themselves with respect to mathematics (Cobb et al., 2009; Martin, 2019; Nasir & Shah, 2011; Oyserman & Lewis, 2017). Second, the mathematics identity measure only captures students' perceptions at one point in time. While the relative stability of mathematics identity for undergraduate students might be expected (Cribbs et al., 2022), there may be much more fluidity with children who are still accumulating mathematical experiences in formal and informal spaces on a daily basis. Future work might explore mathematics identity at various time intervals throughout students' schooling to determine how it might change over time as well as potential factors influencing these changes (e.g., teacher instruction). Additionally, this study explored mathematics identity through one particular perspective, core identity, that does not capture the nuanced picture that might be captured with other perspectives. Cobb and Hodge (2011) described three constructs for analyzing students' mathematics identity: normative, core, and personal. Additional research in this area might expand the fields' understanding of mathematics identity development and extend the work done in this study as well as the work by the field at large. Finally, Darragh and Radovic (2018) discussed the commonly agreed on aspects of mathematics learner identity, which are captured within the measure we created. For example, "learners *ways of being* in the social activity of doing mathematics" (p. 2) draws on work such as Gee (2001) and Cobb et al. (2009) that underpin the theoretical framework used in this study. The aspect of being recognized by others is also captured in our study as we see recognition as essential to identity development as well as capturing how individual's identity is being socially informed. However, one aspect of mathematics identity that is not included

in the current study is the concept of multiple identities, such as gender identity or membership in different communities or groups (Gee, 2001). This aspect of multiple identities has been highlighted in work related to intersectionality (Ibourk et al., 2022; Leyva, 2017). Although this study does not capture the aspect of multiple identities, there is potential to explore these multiple identities in future work using the Mathematics Identity scale.

Conclusion

The purpose of this study was to explore the psychometric properties of the Mathematics Identity scale for grades 5–12. To this end, validation evidence supported the inclusion of 16 items for the scale. This study adds to the field in several ways. First, the mathematics identity scale provides an opportunity for mathematics identity to be explored with larger groups of students and address questions that were potentially challenging prior to having a valid scale for use. In a systematic review of mathematics identity studies conducted between 2014 and 2018, only two of the 47 studies used quantitative methods (Graven & Heyd-Metzuyanim 2019). Additionally, sample sizes for these studies were small ($n \leq 8$) for all except two quantitative studies. A measure for mathematics identity also provides a way to explore areas with limited research, such as connections between learner and teacher identities or teacher practices and mathematics identity development. Researchers and educators can also use the scale to explore the efficacy of learning activities designed to support students' mathematics identity development. Given the important role that mathematics identity has on students' future choices (Cribbs et al., 2016, 2020; Boaler & Greeno, 2000; Boaler & Selling, 2017; Godwin et al., 2016) and outcomes such as achievement (Bohrnstedt et al., 2021), being able to explore this construct efficiently with a scale will benefit the field.

Author contribution Both authors substantially contributed to the study design, implementation, analysis, and writing of this manuscript.

Declarations

Ethics approval IRB approval was attained through Oklahoma State University, IRB-22–78.

Consent to participate A letter of support was received from participating schools, parents were sent an opt-out email, and participants were provided with a consent form prior to any data collection.

Competing interests The authors have any competing interests.

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References

Aguirre, J., Mayfield-Ingram, K., & Martin, D. B. (2013). *The impact of identity in K-8 mathematics learning and teaching: Rethinking equity-based practices*. NCTM.

Ainley, M. (1998). Interest in learning and the disposition of curiosity in secondary students: Investigating process and context. In L. Hoffman, A. Krapp, K. A. Renninger, & J. Baumert (Eds.), *Interest and learning: Proceedings of the Seeon conference on interest and gender* (pp. 257–266). Kiel, Germany: IPN.

Alarcón, D. & Sánchez, J. A. (2015, October 22). *Assessing convergent and discriminant validity in ADHD-R IV rating scale: User-written commands for Average Variance Extracted (AVE), Composite Reliability (CR), and Heterotrait-Monotrait ratio of correlations (HTMT)*. Spanish STATA Meeting. https://www.stata.com/meeting/spain15/abstracts/materials/spain15_alarcon.pdf

American Educational Research Association, Association, A. P., Council, N., & on Measurement in Education. (2014). *Standards for educational and psychological testing*. American Educational Research Association.

Awang, Z. (2015). *A handbook on SEM* (2nd ed.). Universiti Sultan Zainal Abidin.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. Worth Publishers.

Bishop, J. P. (2012). "She's always been the smart one. I've always been the dumb one": Identities in the mathematics classroom. *Journal for Research in Mathematics Education, 43*(1), 34–74. https://doi.org/10.5951/jresematheduc.43.1.0034

Boaler, J., & Greeno, J. G. (2000). Identity, agency, and knowing. In J. Boaler (Ed.), *Multiple perspectives on mathematics teaching and learning* (pp. 171–200). Ablex Publishing.

Boaler, J., & Selling, S. K. (2017). Psychological imprisonment or intellectual freedom? A longitudinal study of contrasting school mathematics approaches and their impact on adults' lives. *Journal for Research in Mathematics Education, 48*(1), 78–105. https://doi.org/10.5951/jresematheduc.48.1.0078

Bohrnstedt, G. W., Cohen, E. D., Yee, D., & Broer, M. (2021). Mathematics identity and discrepancies between self-and reflected appraisals: Their relationships with grade 12 mathematics achievement using new evidence from a US national study. *Social Psychology of Education, 24*(3), 763–788. https://doi.org/10.1007/s11218-021-09631-0

Bohrnstedt, G. W., Zhang, J., Park, B. J., Ikoma, S., Broer, M., & Ogut, B. (2020). Mathematics identity, self-efficacy, interest and their relationships to mathematics achievement: A longitudinal analysis. In R. Serpe, R. Stryker, & B. Powell (Eds.), *Identity and Symbolic Interaction: Deepening Foundations; Building Bridges* (pp. 169–210). Springer.

Bostic, J. D., & Sondergeld, T. A. (2015). Measuring sixth-grade students' problem solving: Validating an instrument addressing the mathematics common core. *School Science and Mathematics, 115*(6), 281–291. https://doi.org/10.1111/ssm.12130

Bostic, J., Krupa, E., & Shih, J. (2019a). *Quantitative measures of mathematical knowledge: Researching instruments and perspectives*. Routledge.

Bostic, J., Krupa, E., & Shih, J. (2019b). *Assessment in mathematics education contexts: Theoretical frameworks and new directions*. Routledge.

Carey, E., Hill, F., Devine, A., & Szucs, D. (2017). The modified abbreviated math anxiety scale: A valid and reliable instrument for use with children. *Frontiers in Psychology, 8*(11), Article 11. https://doi.org/10.3389/fpsyg.2017.00011

Cass, C., Hazari, Z., Cribbs, J., Sadler, P., & Sonnert, G. (2011). *Examining the impact of mathematics identity on the choice of engineering careers for male and female students*. Paper presented at Frontiers in Education Conference, Rapid City, SD.

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching, 44*(8), 1187–1218. https://doi.org/10.1002/tea.20237

Cobb, P., Gresalfi, M., & Hodge, L. L. (2009). An interpretive scheme for analyzing the identities that students develop in mathematics classrooms. *Journal for Research in Mathematics Education, 40*(1), 40–68. https://doi.org/10.5951/jresematheduc.40.1.0040

Cobb, P., & Hodge, L. L. (2011). Culture, identity, and equity in the mathematics classroom. In E. Yackel, K. Gravemeijer, & A. Sfard (Eds.), *A journey in mathematics education research: Insights from the work of Paul Cobb* (pp. 179–195). Springer. https://doi.org/10.1007/978-90-481-9729-3

Comrey, A. L., & Lee, H. B. (2013). *A first course in factor analysis*. Psychology Press.

Cribbs, J., Hazari, Z., Sadler, P. M., & Sonnert, G. (2015). Establishing an explanatory framework for mathematics identity. *Child Development, 86*(4), 1048–1062. https://doi.org/10.1111/cdev.12363

Cribbs, J., Cass, C., Hazari, Z., Sadler, P., & Sonnert, G. (2016). Mathematics and student persistence in engineering. *International Journal of Engineering Education, 32*(1), 163–171.

Cribbs, J., Hazari, Z., Sonnert, G., & Sadler, P. (2020). College students' mathematics-related career intentions and high school mathematics pedagogy through the lens of identity. *Mathematics Education Research Journal*. https://doi.org/10.1007/s13394-020-00319-w

Cribbs, J., Huang, X., & Piatek-Jimenez, K. (2021). Relations of math mindset, math anxiety, math identity, and math self-efficacy to STEM career choice: A structural equation modeling approach. *School Science and Mathematics, 121*(5), 275–287. https://doi.org/10.1111/ssm.12470

Cribbs, J., Tassell, J., Hazari, Z., Sadler, P., & Sonnert, G. (2022). Unpacking mathematics identity: Exploring undergraduate students' enduring experiences. *International Journal for Research in Mathematics Education (RIPEM), 12*(2), 68–91. https://doi.org/10.37001/ripem.v12i2.2923

Darragh, L. (2015). Recognising 'good at mathematics': Using a performative lens for identity. *Mathematics Education Research Journal, 27*, 83–102.

Darragh, L. (2016). Identity research in mathematics education. *Educational Studies in Mathematics, 93*(1), 19–33. https://doi.org/10.1007/s10649-016-9696-5

Darragh, L., & Radovic, D. (2018). Mathematics learner identity. In S. Lerman (Ed.), *Encyclopedia of mathematics education*. Cham, Switzerland: Springer International Publishing.

Department of Employment, Skills, Small and Family Business. (2019). *Employment Outlook to May 2024*. Canberra: DESSFB, December. https://cica.org.au/wp-content/uploads/Employment-Outlook-to-May-2024.pdf

Donolato, E., Toffalini, E., Giofrè, D., Caviola, S., & Mammarella, I. C. (2020). Going beyond mathematics anxiety in primary and middle school students: The role of ego-resiliency in mathematics. *Mind, Brain, and Education, 14*(3), 255–266. https://doi.org/10.1111/mbe.12251

Enyedy, N., Goldberg, J., & Welsh, K. M. (2006). Complex dilemmas of identity and practice. *Science Education, 90*(1), 68–93. https://doi.org/10.1002/sce.20096

Esmonde, I., & Langer-Osuna, J. M. (2013). Power in numbers: Student participation in mathematical discussions in heterogeneous spaces. *Journal for Research in Mathematics Education, 44*(1), 288–315. https://doi.org/10.5951/jresematheduc.44.1.0288

Field, A., Miles, J., & Field, Z. (2012). *Discovering statistics using R*. Sage.

Gee, J. P. (2001). Identity as an analytic lens for research in education. *Review of Research in Education, 25*, 99–125. https://doi.org/10.2307/1167322

Godwin, A., Potvin, G., Hazari, Z., & Lock, R. (2016). Identity, critical agency, and engineering: An affective model for predicting engineering as a career choice. *Journal of Engineering Education, 105*(2), 312–340. https://doi.org/10.1002/jee.20118

Graven, M., & Heyd-Metzuyanim, E. (2019). Mathematics identity research: The state of the art and future directions. *ZDM, 51*(3), 361–377. https://doi.org/10.1007/s11858-019-01050-y

Gresalfi, M., & Hand, V. M. (2019). Coordinating situated identities in mathematics classrooms with sociohistorical narratives: A consideration for design. *ZDM, 51*(3), 493–504. https://doi.org/10.1007/s11858-019-01034-y

Gunderson, E. A., Ramirez, G., Levine, S. C., & Beilock, S. L. (2012). The role of parents and teachers in the development of gender-related math attitudes. *Sex Roles, 66*(3–4), 153–166. https://doi.org/10.1007/s11199-011-9996-2

Harackiewicz, J. M., Smith, J. L., & Priniski, S. J. (2016). Interest matters: The importance of promoting interest in education. *Policy Insights from the Behavioral and Brain Sciences, 3*(2), 220–227. https://doi.org/10.1177/2372732216655542

Harter, S. (1981). A new self-report scale of intrinsic versus extrinsic orientation in the classroom: Motivational and informational components. *Developmental Psychology, 17*(3), 300–312.

Hazari, Z., Sonnert, G., Sadler, P. M., & Shanahan, M. C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching, 47*(8), 978–1003. https://doi.org/10.1002/tea.20363

Hernandez-Martinez, P., Williams, J., Black, L., Davis, P., Pampaka, M., & Wake, G. (2011). Students' views on their transition from school to college mathematics: Rethinking 'transition' as an issue of identity. *Research in Mathematics Education, 13*(2), 119–130. https://doi.org/10.1080/14794802.2011.585824

Holland, D., & Lave, J. (Eds.). (2001). *History in person: Enduring struggles, contentious practice, intimate identities*. School of American Research Press.

Horn, J. (1965). A rationale and test for the number of factors in factor analysis. *Psychometrika, 30*(2), 179–185.

Huang, X., Zhang, J., & Hudson, L. (2019). Impact of math self-efficacy, math anxiety, and growth mindset on math and science career interest for middle school students: The gender moderating effect. *European Journal of Psychology of Education, 34*, 621–640. https://doi.org/10.1007/s10212-018-0403-z

Ibourk, A., Hughes, R., & Mathis, C. (2022). "It is what it is": Using Storied-Identity and intersectionality lenses to understand the trajectory of a young Black woman's science and math identities. *Journal of Research in Science Teaching, 59*(7), 1099–1133.

Ingels, S. J., Pratt, D. J., Herget, D. R., Burns, L. J., Dever, J. A., Ottem, R., Rogers, J. E., Jin, Y., & Leinwand, S. (2011). High school longitudinal study of 2009 (HSLS:09). Base-Year Data File Documentation (NCES 2011–328). Washington, DC: National Center for Education Statistics. http://nces.ed.gov/pubsearch

Kaiser, H. F. (1974). An index of factorial simplicity. *Psychometrika, 39*(1), 31–36.

Kaspersen, E., & Ytterhaug, B. O. (2020). Measuring mathematical identity in lower secondary school. *International Journal of Educational Research*, *103*, 101620. https://doi.org/10.1016/j.ijer.2020.101620

Kelle, U., & Buchholtz, N. (2015). The combination of qualitative and quantitative research methods in mathematics education: A "mixed methods" study on the development of the professional knowledge of teachers. In A. Bikner-Ahsbahs, C. Knipping, & N. Presmeg (Eds.), *Approaches to qualitative research in mathematics education* (pp. 321–361). Springer.

Kincaid, J., Fishburne, R., Rogers, R., & Chissom, B. (1975). *Derivation of new readability formulas (automated readability index, fog count and flesch reading ease formula for navy enlisted personnel. Research Branch Report 8–75.* Millington, TN: Naval Technical Training, U. S. Naval Air Station, Memphis, TN.

Langer-Osuna, J. M. (2017). Authority, identity, and collaborative mathematics. *Journal for Research in Mathematics Education, 48*(3), 237–247. https://doi.org/10.5951/jresematheduc.48.3.0237

Larnell, G. V. (2016). More than just skill: Examining mathematics identities, racialized narratives, and remediation among black undergraduates. *Journal for Research in Mathematics Education, 47*(3), 233–269. https://doi.org/10.5951/jresematheduc.47.3.0233

Larson, M. (2016). A renewed focus on access, equity, and empowerment. NCTM. https://www.nctm.org/News-and-Calendar/Messages-from-the-President/Archive/Matt-Larson/A-Renewed-Focus-on-Access,-Equity,-and-Empowerment/

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of Vocational Behavior, 45*, 79–122.

Lent, R. W., Brown, S. D., & Hackett, G., et al. (1996). Career development from a social cognitive perspective. In D. Brown & L. Brooks (Eds.), *Career choice and development* (3rd ed., pp. 373–422). Jossey-Bass.

Lent, R. W., Sheu, H. B., Singley, D., Schmidt, J. A., Schmidt, L. C., & Gloster, C. S. (2008). Longitudinal relations of self-efficacy to outcome expectations, interests, and major choice goals in engineering students. *Journal of Vocational Behavior, 73*(2), 328–335. https://doi.org/10.1016/j.jvb.2008.07.005

Lesko, A. C., & Corpus, J. H. (2006). Discounting the difficult: How high math-identified women respond to stereotype threat. *Sex Roles, 54*(1), 113–125. https://doi.org/10.1007/s11199-005-8873-2

Leyva, L. A. (2017). Unpacking the male superiority myth and masculinization of mathematics at the intersections: A review of research on gender in mathematics education. *Journal for Research in Mathematics Education, 48*(4), 397–433.

Lutovac, S., & Kaasila, R. (2019). Methodological landscape in research on teacher identity in mathematics education: A review. *ZDM, 51*, 505–515. https://doi.org/10.1007/s11858-018-1009-2

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: The effects of school experiences on earning degrees in STEM. *Science Education, 95*(5), 877–907. https://doi.org/10.1002/sce.20441

Mangu, D. M., Lee, A. R., Middleton, J. A., & Nelson, J. K. (2015). Motivational factors predicting STEM and engineering career intentions for high school students. In 2015 IEEE Frontiers in Education Conference (FIE) (pp. 1–8). IEEE.

Marsh, H. W. (1989). Age and sex effects in multiple dimensions of self-concept: Preadolescence to early adulthood. *Journal of Educational Psychology, 81*(3), 417–430. https://doi.org/10.1037/0022-0663.81.3.417

Martin, D. B. (2000). *Mathematics success and failure among African-American youth: The roles of sociohistorical context, community forces, school influence, and individual agency*. Erlbaum.

Martin, D. B. (2006). Mathematics learning and participation as racialized forms of experience: African American parents speak on the struggle for mathematics literacy. *Mathematical Thinking and Learning, 8*(3), 197–229. https://doi.org/10.1207/s15327833mtl0803_2

Martin, D. B. (2019). Equity, inclusion, and antiblackness in mathematics education. *Race Ethnicity and Education, 22*(4), 459–478. https://doi.org/10.1080/13613324.2019.1592833

Nasir, N. I. S., & Shah, N. (2011). On defense: African American males making sense of racialized narratives in mathematics education. *Journal of African American Males in Education (JAAME), 2*(1), 24–45.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics.* Reston, VA: Author.

National Council of Teachers of Mathematics. (2018a). Catalyzing change in early childhood and elementary mathematics: Initiating critical conversations. Reston, VA: Author.

National Council of Teachers of Mathematics. (2018b). Catalyzing change in middle school mathematics: Initiating critical conversations. Reston, VA: Author.

National Council of Teachers of Mathematics. (2018c). Catalyzing change in high school mathematics: Initiating critical conversations. Reston, VA: Author.

National Council of Teachers of Mathematics. (2020). *Standards for the preparation of secondary mathematics teachers*. Author.

Oyserman, D., & Lewis, N. A., Jr. (2017). Seeing the destination AND the path: Using identity-based motivation to understand and reduce racial disparities in academic achievement. *Social Issues and Policy Review, 11*(1), 159–194. https://doi.org/10.1111/sipr.12030

Radovic, D., Black, L., Williams, J., & Salas, C. E. (2018). Towards conceptual coherence in the research on mathematics learner identity: A systematic review of the literature. *Educational Studies in Mathematics, 99*(1), 21–42. https://doi.org/10.1007/s10649-018-9819-2

Ramirez, G., McDonough, I. M., & Jin, L. (2017). Classroom stress promotes motivated forgetting of mathematics knowledge. *Journal of Educational Psychology, 109*(6), 812–825. https://doi.org/10.1037/edu0000170

Renninger, K. A. (2009). Interest and identity development in instruction: An inductive model. *Educational Psychologist, 44*(2), 105–118. https://doi.org/10.1080/00461520902832392

Renninger, K. A., & Hidi, S. (2016). *The power of interest for motivation and engagement*. Routledge.

Schlomer, G. L., Bauman, S., & Card, N. A. (2010). Best practices for missing data management in counseling psychology. *Journal of Counseling Psychology, 57*(1), 1–10. https://doi.org/10.1037/a0018082

Schumacker, R. E., & Lomax, R. G. (2016). *A beginner's guide to structural equation modeling*. Lawrence Erlbaum Associates.

Schunk, D. H., & Meece, J. L. (2006). Self-efficacy development in adolescence. In T. Urdan & F. Pajares (Eds.), *Self-efficacy beliefs of adolescents* (pp. 71–96). Information Age Publishing.

Sfard, A., & Prusak, A. (2005). *Identity that makes a difference: Substantial learning as closing the gap between actual and designated identities* (pp. 37–52). Paper presented at the Proceedings of the 29th Conference of the International Group for the Psychology of Mathematics Education.

Smith, C. (2010). Choosing more mathematics: Happiness through work? *Research in Mathematics Education, 12*(2), 99–115. https://doi.org/10.1080/14794802.2010.496972

Stavseth, M. R., Clausen, T., & Røislien, J. (2019). How handling missing data may impact conclusions: A comparison of six different imputation methods for categorical questionnaire data. *SAGE Open Medicine, 7*, 1–12. https://doi.org/10.1177/2050312118822912

Stets, J. E., Brenner, P. S., Burke, P. J., & Serpe, R. T. (2017). The science identity and entering a science occupation. *Social Science Research, 64*, 1–14. https://doi.org/10.1016/j.ssresearch.2016.10.016

Su, R., Rounds, J., & Armstrong, P. I. (2009). Men and things, women and people: A meta-analysis of sex differences in interests. *Psychological Bulletin, 135*(6), 859–884. https://doi.org/10.1037/a0017364

U.S. Bureau of Labor Statistics. (2022). Employment projections - 2021–2031. (USDL-22–1805) https://www.bls.gov/news.release/pdf/ecopro.pdf

Wang, J., & Hazari, Z. (2018). Promoting high school students' physics identity through explicit and implicit recognition. *Physical Review Physics Education Research*, *14*(2), 020111. https://doi.org/10.1103/PhysRevPhysEducRes.14.020111

Women in Aerospace Europe. (2021). *STEM education in Europe*. Author. https://www.wia-europe.org/wia-e-working-groups-download/

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