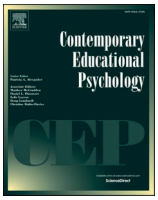
Contemporary Educational Psychology 70 (2022) 102094

Contents lists available at ScienceDirect

Contemporary Educational Psychology

journal homepage: www.elsevier.com/locate/cedpsych



"I have cried in almost all of my math classes." Relations between math self-concept, gender, and narrative appraisals of past low points in math

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ARTICLE INFO

Keywords:
Expectancy-value theory
Math
STEM
Gender
Narrative identity

ABSTRACT

Math self-concept is strongly associated with a range of academic and career outcomes in math. The current research sought to identify factors that distinguish between undergraduates with particularly low or high math self-concept. A sample of 754 college students were asked to recall a low point they had with math as well as respond to questionnaires measuring math self-concept, value, and anxiety. Focal analyses were conducted on a subsample of participants who reported either high (n = 90) or low (n = 94) math self-concept. Relative to participants who had high math self-concept, those with low math self-concept tended to be women, had higher math anxiety, and valued math less. Thematic analysis also revealed similarities and differences in how undergraduates from these two groups appraised challenges, or low points, that they encountered in their history with math. Although there were similarities in the types of low points described by members of these two groups, these experiences were often appraised in distinct ways. Unique themes also emerged for each group, indicating that narrative interpretations of math experiences vary with current levels of math self-concept. Implications for future research and math education are discussed.

1. Introduction

Over the past several decades, research has sought to understand the reasons for the dearth of women in science, technology, engineering, and math (STEM) fields (see Wang & Degol, 2017). This work has led to a variety of interventions aimed at increasing the number of women in STEM (e.g., Master & Meltzoff, 2020; Prieto-Rodriguez et al., 2020; van den Hurk et al., 2019), which has contributed to an overall increase in the number of women in STEM occupations over the past two decades (National Science Foundation, 2018, 2020). There has also been an overall reduction in achievement differences between girls and boys in STEM education, with gender differences in STEM achievement now nearly nonexistent (Hyde et al., 2008; O'dea et al., 2018; Reilly et al., 2015).

Despite these improvements in STEM education and employment, women still make up only about 29% of the STEM workforce, even though they comprise over half of the US population and workforce (National Science Foundation, 2020). Further, although women have reached parity with men in the social and life sciences, gender disparities remain in the most math-intensive STEM fields, where women comprise only 27% of computer science and math occupations, 16% of engineering occupations, and 29% of physical science occupations (National Science Foundation, 2018, 2020). These stubborn gaps in math-intensive STEM fields are concerning for several reasons. First, from a social justice standpoint, gender inequities in STEM are a problem for girls and women who seek to enter STEM but are made to feel as though they do not belong or cannot succeed (e.g., Master & Meltzoff, 2020; Starr & Simpkins, 2021). Second, given that careers in math-intensive STEM fields are lucrative and people with STEM skills are in high demand (Beede et al., 2011; Committee on STEM Education, 2018), these inequities also prevent women from climbing the economic ladder and reaching wage parity with men (Gharehgozli & Atal, 2020). Finally, from a business and economic standpoint, diversity in the workplace has been found to improve innovation, suggesting that workplaces inclusive of all genders may be more successful than those without such diversity (Chrobot-Mason & Aramovich, 2013; Østergaard et al., 2011). For these reasons, it remains a critical task to understand why women remain underrepresented in math-intensive STEM fields.

To address this question, the current research focuses on math self-concept, which has been theoretically and empirically linked to women's underrepresentation in STEM (see Eccles & Wigfield, 2020). Specifically, we sought to identify factors that distinguish between

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https://doi.org/10.1016/j.cedpsych.2022.102094

Available online 1 August 2022
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participants who are particularly low versus high in math self-concept. Using a mixed-methods approach, we examined whether members of these two groups differ in their math motivation and affect as well as in their narrative appraisals of significant challenges, or low points, in their prior history with math. Below, we review the relevant research on math motivation and affect followed by a synthesis of this literature with existing work on narrative identity development.

1.1. Self-concept, values, and achievement emotions

Although gender differences in math achievement have all but disappeared (e.g., Reilly et al., 2015), significant gender differences remain in math self-concept, which influences motivation and persistence in math (e.g., Dietrich & Lazarides, 2019; Jiang et al., 2020; Lauermann et al., 2017) and contributes to STEM career aspirations (Kwon et al., 2019; Seo et al., 2019; Willie et al., 2020). *Academic self-concept* refers to an individual's overall perception of their competence in a domain (Bong & Skaalvik, 2003; Wigfield & Eccles, 2000). Therefore, *math self-concept* may refer to a person's perception of their own math abilities. In general, higher academic self-concept is related to higher valuation of a domain (Arens et al., 2019; Nagy et al., 2006; Wang et al., 2021), and is also consistently associated with better outcomes in a domain, such as pursuit, persistence, and performance (Eccles, 1983; Wigfield & Eccles, 2020; Wigfield & Eccles, 2000). Regarding the math domain, boys consistently report higher math self-concept than do girls (Pajares, 2002; 2005). These gender differences typically emerge during early adolescence and increase with age. Interestingly, even when they report higher math achievement relative to boys and men, girls and women rarely report higher math self-concept (Huang, 2013; Robnett & Thoman, 2017; Skaalvik & Skaalvik, 2004).

According to situated expectancy-value theory (SEVT) (Eccles & Wigfield, 2020), self-concept is determined by a variety of contextual forces. These forces include stereotypes, societal expectations, the attitudes of important socializers (e.g., parents, teachers, and peers), and an individual's own interpretations of what these contextual forces mean. SEVT also proposes that self-concept is informed by cognitive and affective interpretations (i.e., appraisals) of past achievement experiences. These appraisals often focus on performance relative to the peer group as well as performance within and across different academic domains (e.g., math vs. English; Bong & Skaalvik, 2003; Gaspard et al., 2018).

The control-value theory of achievement emotions (CVT; Pekrun et al., 2007) expands upon the affective interpretation process proposed in SEVT by explaining how individual differences in emotion appraisal mediate the relations between self-concept, values, and achievement outcomes. More specifically, according to CVT, self-concept and related expectancies for success directly influence how much *control* an individual feels they have over an achievement outcome. The *value* a person attributes to an achievement outcome is dependent on both how much interest an individual has in a particular domain (e.g., intrinsic value) and how important it is for the individual to be successful in the domain (e.g., extrinsic value, Frenzel et al., 2007). For instance, feelings of high control and high value are generally related to positive emotions about a task and subsequent positive outcomes on the task. These positive experiences then strengthen feelings of control and value for future tasks. On the other hand, feelings of low control and low value are generally related to negative emotions about a task and, subsequently, more negative outcomes on the task. These negative experiences then further reduce feelings of control and value for future tasks.

CVT can help to explain the gender differences typically seen in math-related emotions and math outcomes. For example, Frenzel and colleagues (2007) found that the association between gender and emotions toward math was mediated by both math self-concept and value. More specifically, girls' greater negative emotions toward math could be explained by low competence beliefs and low intrinsic value in math, as well as high levels of extrinsic value in math. In other words, for girls, low confidence in their math skills and low interest in math, combined with the acknowledgement that math skills are important, increased their negative emotionality toward math. According to CVT, this negative emotionality toward math is likely to result in more negative math outcomes for girls.

This notion is also corroborated by the literature on math anxiety, which is a well-known type of negative emotionality towards math. More specifically, *math anxiety* is a fear of situations involving math that may be present in both academic and everyday settings (Ashcraft, 2002). Notably, there are consistent gender differences in self-reported math anxiety, with girls reporting higher math anxiety than boys (Ma, 1999). In addition, higher math anxiety is consistently associated with poorer math outcomes, including a significant reduction in math performance, self-concept, and value (Ahmed et al., 2012; Hembree, 1990; Barroso et al., 2021) as well as a reduced likelihood of pursuing STEM careers (Ahmed, 2018).

1.2. Narrative appraisals

SEVT and CVT help to explain the process by which self-concept, values, and emotion appraisals are reciprocally related and ultimately influence achievement outcomes and future aspirations. However, the narrative identity literature provides a framework to more deeply consider how these experiences become incorporated into a person's identity over time and may ultimately influence their future plans. According to McAdams (2001), a person's identity typically takes the form of a narrative, or story, that provides the individual with a coherent sense of purpose. The construction of a life story begins during late adolescence, which is when individuals are first cognitively able to meaningfully reflect on their past experiences, attend to their present situations, and use this knowledge to anticipate their futures. During this time, adolescents and young adults use narratives to consolidate their beliefs and experiences into a personal ideology that they can use to make future plans such as choosing a career. A key component of narrative identity development is the process of assigning meaning to past experiences to create a coherent account of one's identity over time (McAdams & McLean, 2013). The meaning-making process is also heavily influenced by broader cultural values, norms, and stereotypes (McAdams, 2008). These sociocultural components of identity give rise to "master narratives," which serve as rigid prototypes for how a person's life should play out, given their own personal characteristics (McLean & Lilgendahl, 2019; McLean et al., 2019).

Traditional master narratives typically uphold conventional gender roles and systems of gender inequity (McLean et al., 2016). Given the pervasiveness of gendered math-ability stereotypes in the U.S., a traditional master narrative likely exists where men are favored as more naturally suited for math-intensive careers than are women (Cerva, 2019; Zavala & Hand, 2019). Though it is possible to resist master narratives by creating alternate narratives, master narratives provide a straightforward way for an individual to structure a coherent life story. In this way, aligning one's identity with a master narrative requires less psychological labor; individuals who resist the master narrative are required to engage in substantively more difficult identity work (McLean et al., 2020).

Emotion plays a key role in how narrative identity is created. In particular, emotions and personal goals are closely linked in the theory of narrative identity development (McAdams, 2001). For instance, when a person feels an emotion during a life experience, they make an appraisal of what the event might mean for them in terms of achieving some goal (or not). These appraisal patterns are highly individual and allow a person to create their narrative identity either through a matching or re-alignment of past experiences with current personal goals (Roseman & Smith, 2001). *Personal event memories* are vivid, detailed, and emotionally charged recollections of specific events, and are most often remembered when an individual attaches some symbolic meaning to the event (McAdams, 2001). For instance, if an adolescent girl experiences anxiety and performs poorly on a math test, she may

interpret the event as meaning that she is bad at math, which aligns with the larger master narrative of gendered math abilities. If similar experiences and emotions continue over time, they can create *self-defining memories* (Singer, 1995). Given that a core component of narrative identity is to integrate past experiences with future goals (McAdams & McLean, 2013), these self-defining memories likely compel a re-evaluation of existing personal goals. For instance, the adolescent girl may use her unpleasant past experiences and emotions towards math to re-evaluate her confidence in the math domain and re-align her goals with a future that does not involve math. In doing so, she increases the coherence of her life story (Habermas & Bluck, 2000).

The process of narrative identity development helps to establish the reciprocal relation between an individual's interpretation of their contextualized experiences and outcomes. This work, alongside SEVT and CVT, can also explain why people who experience similar events might interpret them in distinct ways. For instance, in a culture with traditional master narratives about gendered math ability, a girl who has had difficulties with math in the past may appraise her anxiety about a math task as an indicator that she lacks math ability and cannot succeed, whereas a boy who has not had difficulty with math may appraise his anxiety about the same task as motivation to succeed (e.g., Pekrun & Stephens, 2010). Relatedly, a girl who succeeds on a math task may attribute her success to external factors, such as hard work, whereas a boy who succeeds on the same math task might attribute his success to internal factors, such as natural ability (Meece et al., 2006).

1.3. A mixed-methods approach

Decades of theoretical and empirical work have established reciprocal associations among self-concept, values, emotions, and achievement outcomes in various domains (e.g., Frenzel et al., 2007; McAdams & Mclean, 2013; Wigfield & Eccles, 2000). However, despite its theoretical value, only a handful of prior studies have investigated how an individual's narrative interpretation of their past experiences might influence these variables (see Eccles & Wigfield, 2020). In one of these studies, John et al. (2020) asked undergraduates about significant turning points in their prior history with math. Findings showed that participants whose narratives reflected a longstanding positive orientation toward math tended to have more positive math attitudes compared to participants who wrote other types of turning point narratives. In addition, some qualitative work on the influence of master narratives regarding gender roles and gendered ability beliefs suggests that using a narrative identity framework to understand the gender gaps in math-intensive STEM may be particularly illuminating (McLean et al., 2016; McLean et al., 2019; Zavala & Hand, 2019).

The current study builds on this emergent body of work by using a mixed-methods design to examine (1) how participants remember and narrate a past math experience and (2) whether these narratives are associated with participants' current level of math self-concept. In the current study, we examine how participants narrate especially negative experiences ("low points") in their history with math. Analyses focus on participants with particularly low or high math self-concept. By comparing low points among participants on differing ends of the math self-concept continuum, the current study attempts to shed light on how differences in math self-concept relate to individual differences in narrative interpretation of past math events. Given the existing quantitative work on SEVT and CVT, as well as the qualitative work on narrative identity, a mixed-methods approach provides an ideal way to bridge these complementary perspectives. In addition, a strength of mixed methods lies in its ability to maximize the strengths of both qualitative and quantitative methodologies while also minimizing the weaknesses of each (McCrudden et al., 2019).

The decision to compare participants with particularly high versus low levels of math self-concept was informed by the growing person-centered literature on math achievement motivation. Traditional variable-centered approaches assume that all individuals derive from a single population, whereas person-centered approaches identify groups of individuals who may derive from different sub-populations (see Howard & Hoffman, 2018; Marsh et al., 2009 for a review). Person-centered research that examines achievement motivation in math has been fruitful in helping to explain individual variation in a range of important academic outcomes such as interest, performance, and persistence in math-related fields (Chow et al., 2012; Lazarides et al., 2020; Lin et al., 2018). By extension, the current study's approach of comparing participants with differing levels of math self-concept should provide insight into specific events and appraisal patterns that contribute to qualitatively different math outcomes. In addition to building on existing empirical work, insights gleaned from the current study's comparative approach may be useful in designing tailored interventions that support students who display particularly low levels of math self-concept.

1.4. Current study

The current mixed-methods study examines how participants with particularly high or low math self-concept narrated their memories of a low point in math. Given the theoretical and empirical work associating math self-concept with important math outcomes, as well as recent work suggesting that narrative appraisals of past math experiences are associated with current math outcomes, we were interested in examining how participants' narrative interpretations of a math low point might vary with their current level of math self-concept. We not only aimed to uncover gender differences in these responses, but also sought to identify particularly poignant themes in the narration of these math experiences that might serve as engines for further research and intervention in math education. More specifically, we proposed the following hypotheses and research questions:

H1: There will be gender differences in the composition of the high and low math self-concept groups;

H2: Participants in the high math self-concept group will report lower math anxiety and higher math value than participants in the low math self-concept group;

RQ1: What are the similarities and differences in how participants with high and low math self-concepts narrate their math low points?

RQ2: Are there gender differences in the themes participants mention while narrating their math low points?

In examining these hypotheses and research questions, we conducted exploratory analyses testing for mean ethnic-racial differences when the sample size was sufficient. Although race and ethnicity were not a focal point in the current research, we reasoned that these exploratory analyses could help to inform future work that aims to understand racial-ethnic differences in STEM outcomes.

2. Method

2.1. Participants

A total of 754 undergraduates were recruited from a large, public university in the Southwestern U.S. Participants completed an online survey for course credit either during the fall semester of 2018 or the spring semester of 2019. All participants were enrolled in introductory psychology, which is a general education course taken by students from a variety of majors. Nearly all participants (97%) were between the ages of 18 and 34. Forty-six percent of the sample indicated that they were first generation college students. The full sample included 487 women (65%), 257 men (34%), three transgender men (<1%) and two transgender women (<1%). Five participants (<1%) did not indicate their gender identity. With respect to ethnic background, 244 participants (32%) identified as White, 210 participants (28%) identified as Hispanic/Latinx, 175 participants (23%) identified as Asian/Pacific Islander, 81 participants (11%) identified as Black/African American, 32 participants (4%) identified as "other", 8 participants (1%) identified as

Native American/American Indian, and four participants (<1%) did not indicate their race. Multiracial participants who identified with ethnic groups that are both underrepresented and overrepresented in STEM (e.g., Hispanic/Latinx and White) were grouped into the underrepresented ethnic-racial category in the exploratory analyses. The full sample was used to confirm the two-factor structure of the abbreviated math anxiety scale, as well as to test for mean gender differences in math self-concept, math value, and math anxiety. As described below, the focal analyses for this paper were conducted on a subset ($n = 184$) of the full sample with particularly low or high math self-concept.

2.2. Procedure

Participants were recruited to participate in one of two anonymous online surveys through the university's introductory psychology subject pool. Some of the participants who took part in the current study also participated in a prior study focusing on past math experiences (John et al., 2020). The survey used to collect data for both studies was first administered in spring of 2018 and again in spring of 2019. Participants from 2018 were prohibited from participating again in 2019. The data used for John et al. (2020) were from the 2018 survey only, whereas the data for the current study include participants from both administrations of the survey. In addition to having a substantively different conceptual focus, the current study differs from John et al. (2020) in terms of its analytic approach. Informed consent was obtained from all participants prior to beginning the survey. The survey included a demographic questionnaire, scales assessing math-related outcomes and general resilience, and several open-ended questions pertaining to participants' math-related experiences. The quantitative measures used in the current study are described below, followed by a description of the qualitative method for prompting participants to narrate a low point they had with math. The corresponding qualitative coding process is also discussed.

2.3. Quantitative measures

Math Self-Concept. Math self-concept was assessed using the corresponding nine items from Watt et al. (2012) math-specific expectancy-value measure. This measure asked participants to rate their agreement with the items on a scale from 1 (*disagree strongly*) to 6 (*strongly agree*). Sample items include "I am better at math than I am at other academic subjects" and "Math is fairly easy for me," with higher scores indicating higher math self-concept. This scale had excellent internal reliability ($\alpha = .92$).

Math Value. Math value was assessed using six items from Watt et al. (2012) math-specific expectancy-value measure. This measure asked participants to rate their agreement with the items on a scale from 1 (*disagree strongly*) to 6 (*strongly agree*). Sample items include "I find it interesting to work on math projects and assignments" and "What I learn in math is useful for my daily life outside of school," with higher scores indicating higher math value. This scale had good internal reliability ($\alpha = .81$).

Math Anxiety. Two components of math anxiety were assessed using the abbreviated math anxiety scale (Hopko et al., 2003). The nine-item measure includes scenarios that are intended to capture the degree of anxiety caused by both learning and evaluation contexts in math. Participants were asked to rate the amount of anxiety caused by each scenario on a scale of 1 (*low anxiety*) to 5 (*high anxiety*). Five items assess learning math anxiety (e.g., "Listening to a lecture in math class") and four items assess evaluation math anxiety (e.g., "Taking an examination in a math course"), with higher scores reflecting higher levels of math anxiety. The learning math anxiety subscale had good internal reliability ($\alpha = .86$), and the evaluation math anxiety subscale had excellent internal reliability ($\alpha = .90$).

2.4. Math low point

The current study sought to understand how participants recalled a "low point" in their math education. We employed a math-specific version of McAdams (2008) life story approach, wherein all participants were encouraged to share a low point they had experienced with math in the past. The instructions began by asking participants to describe a past math-related episode that stood out as a particularly negative experience and asked them to elaborate in detail about when the event occurred, who was involved, and what they were thinking and feeling at the time. Instructions for the math-specific life story approach can be found in Appendix A.

Our analysis of math low points is focused on 184 participants who scored either one standard deviation above ($n = 90$, 12%) or one standard deviation below ($n = 94$, 12.5%) the calculated mean for math self-concept in the full sample ($M = 2.92$, $SD = 1.38$), resulting in one group with relatively high math self-concept (*High MSC*, $M \geq 4.30$) and one group with relatively low math self-concept (*Low MSC*, $M \leq 1.54$). Full demographic details for the two groups can be found in Table 1.

Qualitative coding. We used the steps for thematic analysis outlined by Braun and Clarke (2006) to examine themes in participants' qualitative responses. To begin, the first author read the full corpus of data and developed two coding manuals using a primarily inductive (i.e., data-driven) approach. Throughout the process of familiarizing themselves with the data, the first author noticed that there were both commonalities and uniqueness in the themes identified within the high and low MSC groups. As such, two separate coding manuals were developed to best capture the qualitative data from each group. Themes from each coding manual were not mutually exclusive, meaning that participant responses could be coded under multiple themes. Following several revisions to the coding manuals, the second author and two

Table 1
Demographics for high and low MSC groups.

Demographic Variable	High MSC		Low MSC	
	n	%	*n*	%
Age				
18–24	83	92	84	90
25–34	7	8	7	7
35–44	0	0	3	3
Gender				
Male	32	36	17	18
Female	57	63	75	80
Trans Male	0	0	1	1
Trans Female	1	1	1	1
Race				
White	29	32	37	39
Hispanic/Latinx	21	23	28	30
Asian/Pacific Islander	25	28	15	16
Black/African American	9	10	12	13
Other	6	7	2	2
Education Level				
1st Year College Student	43	48	37	40
2nd Year College Student	19	21	18	19
3rd Year College Student	16	18	22	23
4th Year College Student	8	9	7	7
5th Year College Student or Beyond	2	2	8	9
Bachelor's Degree	1	1	1	1
Other	1	1	1	1
First Generation Status				
Yes	39	44	47	50
No	50	56	47	50

Note. $N = 90$ for the High MSC group and $N = 94$ for the Low MSC group. Valid percentages are reported.

trained research assistants used the manuals to separately code approximately 20% of the qualitative responses. Although Braun and Clarke (2006) do not require testing for interrater reliability in thematic analysis, other researchers have argued that interrater reliability is important for establishing replicability and rigor in qualitative data analysis (Syed & Nelson, 2015). Interrater reliability, indexed by Cohen's kappa (*K*), was high for both coding manuals: High MSC (K = 0.86–0.91); Low MSC (K = 0.84–1.00). Once interrater reliability was achieved, the two research assistants separately coded the remaining qualitative data. The second author and research assistants included an additional test of interrater reliability on the remaining data to ensure that agreement remained high throughout the coding process (K = 0.78–1.00). Disagreements were resolved through dialogue until consensus was reached.

Regarding the High MSC group, the qualitative coding process yielded five themes (for a summary of qualitative themes, see Table 2a). Valid percentages are reported for all coding categories. The most common theme for this group was *negative affective experience* (n = 42, 52%), followed by *teacher* (n = 23, 28%), *first time ability challenge* (n = 16, 20%), *bad grade* (n = 13, 16%), and *geometry* (n = 12, 15%). Regarding the Low MSC group, the qualitative process yielded six - themes (see Table 2b). The most common theme for this group was - *negative affective experience* (n = 53, 65%), followed by *bad grade* (n = 37, 46%), *teacher* (n = 34, 42%), *math aversion* (n = 31, 38%), *critical realization* (n = 15, 19%), and *upward comparisons* (n = 10, 12%). The themes for both groups are described in more detail below.

Table 2a
High math self-concept: low point themes.

Theme	Definition	Example Quote
Negative Affective Experience	Participants mention some type of negative emotionality related to their math low point.	"By the end of the study session, I was on the verge of tears… I sat [stayed] behind with the teacher, and asked her what I was doing wrong… I cried to her, and I was vulnerable to my emotions."
Teacher	Participants attribute at least a portion of their low point to their teacher. These responses often include feeling discouraged or unsupported by their teacher.	"In my first semester of college, my first math teacher was horrendous. She did not teach rather just gave us notes…This made me think that all math courses in college were a waste and that no one could truly pass math successfully."
First Time Ability Challenge	Participants mention having their math abilities challenged for the first time, often while struggling to understand the material.	"I was in Calculus class my freshmen year in college and it was the first time taking a college math class and I believed that it would be fairly similar to high school… I have never struggled in math…I became extremely frustrated as to why I couldn't retain the information like I used to."
Bad Grade – Low Effort/ Overconfident	Participants attribute at least part of their low point to receiving a bad grade or a lower grade than they expected. These participants also often mention that their bad grade was due to low effort or overconfidence.	"I can easily say that I was one of the smartest kids in the class… the unpleasant event, it was a test… I did not study at all because I believed that I was going to get an A regardless. I just thought I was that good… but there were some…word problems that I completely forgot how to solve. It stressed me out so much…"
Geometry	Participants mention that Geometry contributed to a particular low point in their math experience.	"My freshmen year of high school math was extremely hard purely because of the existence of geometry."

Table 2b
Low math self-concept: low point themes.

Theme	Definition	Example Quote
Negative Affective Experience	Participants mention some type of negative emotionally related to their low point.	"My grades were doing fairly well up until I took the first exam of the class. It had completely destroyed my grade …This took a toll on me mentally. I would suffer anxiety before every class especially before tests to the point where sometimes I would even cry while studying because I knew that there was no way I could do well on it."
Bad Grade	Participants attribute at least part of their low point to receiving a bad or lower grade than they expected in a math class, math test or assignment.	It was about the time to take my last exam in class before the final. I studied so hard, every night, and even got a tutor…I saw the next week, I received an F. I cried in class because I was stressed."
Teacher	Participants explain at least a portion of their low point was caused by their teacher not being supportive or creating a bad experience for the participants in some way.	"My teacher was basically a bully… I asked a question [and] he would make me feel like I was pretty stupid in front of the class. I was super shy in middle school and extremely intimidated by him. He would praise those who were excelling and berate those or get offended by those who just didn't understand."
Math Aversion	Participants mention some type or fixed or long-term lack of math ability, struggle with math, or dislike of math.	"I had always had trouble with math and even when I tried to get better at it, I still could not do it."
Critical Realization	Participants allude to the notion that their low point was a critical moment in their relationship with math. These responses often mention some type of realization or discovery regarding their feeling about math or their future with math.	"I was trying to get some help… on my math homework… I could feel myself getting worse and worse at the problems… This eventually led to me developing a hate and high stress in relation to math, because every other subject I had ever learned I did well in… this moment was specifically a low point is because it made me realize that I wasn't a 'super, above average student' anymore.
Upwards Comparisons	Participants mention external pressure caused by comparing themselves to others. Participants often mentioned feeling as though they were not performing as well or were not as capable as their peers.	"During an exam in my pre-calculus class… I glanced around at my peers, who were scribbling their answers without breaking a sweat… Seeing everyone around me doing fine with the exam made my struggle with it that much more. I felt so dejected…"

3. Results

3.1. Preliminary analyses

A confirmatory factor analysis (CFA) established the expected two-factor dimensionality of the AMAS in the full sample, indicating one factor for learning math anxiety and a second factor for evaluation math anxiety (for a similar pattern, see Hopko et al., 2003). Preliminary quantitative analyses replicated gender differences obtained in prior

work in that men, when compared to women, reported significantly higher math self-concept and significantly lower learning and evaluation math anxiety. We found no gender differences with respect to overall math value in the full sample. A summary of these results can be found in the online supplemental material.

Our core findings are presented below in three sections. First, we present a preliminary analysis of gender differences in high and low MSC group composition, in addition to group differences in math value and math anxiety. We also include an exploratory analysis of ethnic-racial differences in high and low MSC group composition as well as racial differences in math value and math anxiety. Next, we provide a qualitative analysis detailing how participants in the high and low MSC groups narrated their math low points. Finally, we present a mixed-methods analysis of gender differences in the themes used to describe math low points for the high and low MSC groups. Cohen's (1988) heuristics are used when discussing small (0.10–0.30), medium (0.30–0.50), and large (0.50 +) effect sizes for Cramer's V. Valid percentages are reported for all chi-square analyses, and inspection of standardized residuals was used to determine which group was driving any significant differences. With respect to partial eta squared, Cohen's effect size ranges correspond to values of 0.01–0.06 (small), 0.06–0.14 (medium), and 0.14+ (large; Lenhard & Lenhard, 2016). Due to power constraints, all quantitative gender analyses were completed using participants who identified within the gender binary (e.g., man or woman); however, responses from transgender and nonbinary participants were included in the qualitative analysis.

3.2. Quantitative comparisons between high and low MSC groups

Our first hypothesis (H1) predicted that there would be gender differences in the composition of the high and low MSC groups. Chi-square analysis and the evaluation of standardized residuals supported this hypothesis, with men comprising only 18.5% of the low MSC group, $\chi^2(1, N = 172) = 6.99$, $p = .008$, $V = 0.197$. This result indicates a small effect that aligns with gender differences found in prior research on math self-concept as well as the gender differences found in math self-concept in the full sample.

Given the diversity of our sample, we explored whether racial differences existed in the composition of the high and low MSC groups. Chi-square analysis and the evaluation of standardized residuals indicated no racial differences in the composition of the high and low MSC groups, $\chi^2(3, N = 176) = 4.544$, $p = .208$, $V = 0.161$. In contrast, a four-group MANOVA using the four largest racial groups from the full sample (White, Hispanic/Latinx, Asian/Pacific Islander, and African American/Black) revealed significant racial differences in the linear combination of learning math anxiety, evaluation math anxiety, math self-concept, and math value, $\Lambda = 0.853$, $F(4, 12) = 2.313$, $p = .004$. Follow-up univariate ANOVAs indicated a significant racial difference in math value only, $F(3, 172) = 2.689$, $p = .048$, Adj. $\eta_p^2 = 0.028$ (see Mordkoff, 2019 for a discussion of adjusted eta-squared), which constitutes a small effect. However, inspection of Bonferroni corrected pairwise comparisons indicated that Asian/Pacific Islander participants only reported marginally higher math value ($M = 3.938$) than did White ($M = 3.320$, $p = .074$) and Hispanic/Latinx participants ($M = 3.285$, $p = .078$), but not African American/Black participants ($M = 3.540$, $p = 1.00$). Overall, our analysis is not indicative of racial differences in math self-concept and related math outcomes in the current sample.

Our second hypothesis (H2) predicted that participants in the high MSC group would report lower math anxiety and higher math value than participants in the low MSC group. A two-group MANCOVA with gender specified as a covariate revealed significant group differences on the linear combination of learning math anxiety, evaluation math anxiety, and math value, Hotelling's $T^2 = 314.035$, $F(3, 176) = 101.759$, $p < .001$. As illustrated in Table 3, follow-up univariate ANOVAs indicated that participants in the high MSC group reported significantly lower learning math anxiety (Adj. $\eta_p^2 = 0.321$), lower evaluation math anxiety (Adj. $\eta_p^2 = 0.495$), and higher math value (Adj. $\eta_p^2 = 0.433$), than did participants in the low MSC group. These results constitute large effect sizes, although they are likely inflated due to the focus on high and low MSC groups. Importantly, gender was not a significant covariate, Hotelling's $T^2 = 7.783$, $F(3, 176) = 2.503$, $p = .061$, indicating that the gender binary does not explain additional variance in the linear combination of learning math anxiety, evaluation math anxiety, and math value after accounting for high and low levels of math self-concept. Overall, these results support our second hypothesis, but they do not shed light on why such disparate math outcomes exist between participants with high and low MSC. Our qualitative analyses aim to identify possible explanations for these outcomes.

Table 3
Mean gender differences in math outcome variables.

	Men	Women		MANOVA Test Statistics	
	M (*SD*)	*M* (*SD*)	*F*	*p*	η_p^2
Learning Math Anxiety	1.44_a (0.62)	2.64_b(0.99)	101.76	<0.001	0.632
Evaluation Math Anxiety	2.61_a (1.15)	4.50_b (0.63)			
Math Value	4.31_a (1.23)	2.71_b (0.96)			

Note. $N = 181$. Means with different subscripts are significant between men and women at the $p < .001$ level.

3.3. Qualitative comparisons between high and low MSC groups

A key goal of the current study was to better understand how participants remember and narrate a particularly negative experience they had with math and examine whether different types of narratives are associated with participants' current level of math self-concept (RQ1). As previously mentioned, a primarily inductive approach was used to analyze the qualitative data, which allowed the researchers to identify themes in the data without prior theory or expectation. First, we present themes that were similar in content but differed in how they were discussed by the participants in each of the two groups. Next, we detail themes that were unique to each group.

Similar low point themes. The narrative data yielded several "low point" themes that were similar in content across both the High MSC and Low MSC groups. Importantly, however, these themes often differed in terms of emotional valence or outcome. The themes that were similar between both groups included the following: *bad grade*, *negative affective experiences,* and *teacher*.

The *bad grade* theme identified students who at least partially attributed their low point to receiving either (a) an objectively bad grade (e.g., failing) or (b) a lower grade than they expected to receive. High MSC students primarily discussed this theme in terms of receiving a lower grade than they expected, rather than what might more objectively be considered a "bad" grade (e.g., failing). Second, High MSC students often attributed the cause of their bad grade to two internal factors: a lack of effort in their own attempts to learn the material or overconfidence in their knowledge of the subject matter at the time. For example, Demi[1] explained how her high math confidence undermined her performance in a college math course: "I believed, since I had always done well in math, it would be the one class I didn't have to try as hard in… I ended up with a B in that class, which was the first time I had received anything less than an A in math." This response exemplifies how High MSC students often considered a lower-than-expected grade (e.g., receiving a "B"), as opposed to a failing grade, to be a low point. Another participant, Roman, indicated how his lack of studying contributed to a failing test grade:

[1] All names are pseudonyms.

> "We were finishing a chapter with topics that I did not feel completely comfortable with, but I decided I did not need to study as I thought I would be fine. The next day we had our chapter test and I felt confident in my abilities, however when taking the test, I realized I did not know how to do most of the problems. I was thoroughly disappoint[ed] in myself that I did not study and that test ended up being the first and only math test I have ever failed."

Whereas High MSC participants typically attributed receiving a poor or lower-than-expected grade to low effort or overconfidence, Low MSC participants not only discussed failing grades more often, but also provided a wider range of internal attributions for their grades. These attributions included low effort, frustration, and difficulty understanding the material, which are exemplified in Eric's response: "I quickly fell behind [in algebra]. This failure to understand topics led to a disheartening feeling towards homework. A lack of desire to do homework led to a failure to understand topics. This cycle ensued for my entire sophomore school year. This algebra class was the first ever time I received a C grade in a class." Interestingly, several low MSC participants referenced *math aversion* alongside the *bad grade* theme, sometimes as an attribution for why they received a bad grade. For example, Esme described a difficult experience with a math course that contributed to her math aversion:

> "… I was extremely nervous, especially since math is not my strong suit at all. As soon as the class began, the professor immediately jumped into the lesson with no hesitation. Being that math is a hard subject for me to grasp, I became very overwhelmed by all the new material being thrown at me … As the quarter went on, I still wasn't understanding anything and I was also failing every test and quiz. Though [my friend] tried to teach me the lessons herself after class, I still wasn't able to grasp the material. I stopped going to the class and ended up with an F on my transcript."

In addition, some Low MSC participants mentioned receiving a bad grade despite their concerted efforts to study or understand the material. For instance, Katie mentioned the amount of effort she put into studying for an exam, only to receive a failing grade: "On my first math test I studied day and night and I had my friend try to tutor me because it was really hard. I felt so confident about how I wanted to do so I took my math test and it felt like no struggle at all. Then when I got my results, I saw that I failed my first math test." Another participant mentions failing a course, even after studying hard and asking for help: "It was the first class I was failing in ever. It seemed like no matter how much I studied [or] how much I asked for help, I couldn't get it right." This same participant also notes that this experience directly influenced her dislike for math when she says, "…ever since then, it seems like I still can't stand math. I will try my best to avoid it.".

The *negative affective experiences* theme encompassed responses that included a negative emotional component, which was frequent across both High MSC and Low MSC groups when discussing math low points. For High MSC participants, the most referenced negative emotions included feelings of frustration (e.g., "The whole class was just extremely frustrating"), stress (e.g., "it stressed me out so much"), embarrassment, (e.g., "I was so embarrassed with myself"), and more generally feeling "upset." For example, Nadia recalled an experience where she struggled to understand the material, stating "I was extremely upset with myself because I truly did not understand the concepts that we were learning in class…" Another participant recalled, "I have never been so upset by math in all my life." Interestingly, High MSC participants typically referenced these emotions in reference to feeling confused about the material, or with regard to taking a particularly difficult exam. Amy's response exemplifies this tendency:

> "For the final last semester, I felt extremely rushed and I thought I knew what I was doing. For the whole [two] hours I was typing numbers in my calculator frantically and I still did not finish the exam … Probably the most stress I have ever felt on an exam and especially a math class. I was extremely stressed, mad, and angry at myself for not understanding it."

The *negative affective experiences* reported by Low MSC participants were similar to those mentioned most frequently by the High MSC students, including references to feelings of frustration (e.g., "I became very frustrated"), stress (e.g., "this class really stresses me out"), and embarrassment (e.g., "I felt embarrassed in front of my peers"). Notably, Low MSC participants elaborated on their negative emotions more than did High MSC participants, often referencing more than one negative emotion in their responses and providing more context for why the negative emotions occurred. Low MSC participants also made more references to anxiety, specifically, than did High MSC participants. For example, Mya recalled a particularly difficult test experience, where she felt aggravated, dejected, embarrassed, and anxious:

> "Seeing everyone around me doing fine with the exam made my struggle with it that much more aggravating … I felt so dejected … I considered writing a note to my teacher on the exam, apologizing and explaining why most of the exam was blank. Instead, I tried to ignore my warm face and embarrassment as I wrote down answers that I knew were probably wrong. I strained myself, trying to remember every lecture up to that point, in order to solve the problems before me…That has basically been my experience with math my entire life – getting anxious and dejected when I can't figure the problems out…"

Another participant clearly details her lived experience with math evaluation anxiety, and how it has affected her *math aversion* over time:

> "In every math class I have taken I have ALWAYS experienced this issue and traumatic event. I will prepare myself for an exam a week prior … When the exam day hits, I get major test anxiety, and I have to take a few deep breathes before starting. I start my test with my heart racing because I have anxiety. My test anxiety heightens as I see my peers get up from their seats, and hand in their tests. I tend to get jittery at this point because I am not sure if I am slower or faster than my peers who are taking the test. My heart is still racing as I finish my exam, and I look over my answers one to two times … My anxiety … heightens once I get home, as I lay thinking about my score. I check my grade, and it is not the grade I wanted to have after studying. I cry, and my negative thoughts spread … I always felt like math wasn't my strongest suit, and I had to work harder than others to understand … I question what I did wrong as a person or if I am just stupid. Math in general gives me bad vibes as I am scared to try or even answer simple math problems without doubting the answer."

Low MSC participants also referenced behaviors that typically accompany negative emotions, such as crying, more often than did High MSC participants. This can be seen in the example above, in addition to another participant who stated, "The most stressful experience I had with math was taking Algebra 2 Honors. In that class, I felt like crying all the time." Another student mentioned feeling "so discouraged" and "worthless" because of her math exam performance that she went home and cried afterward. In general, the *negative affective experiences* theme encompassed a wide range of negative emotions that participants felt in their math low points for both High MSC and Low MSC participants. Although there was quite a bit of overlap in the types of negative emotions mentioned by both groups, the ways in which the emotions were described and explained indicates that Low MSC individuals experienced a wider breadth of negative emotions as well as a wider variety of experiences that caused those negative emotions.

Finally, both High MSC and Low MSC participants referenced *teachers* as key components in their math low points. The *teachers* theme included responses that mentioned a teacher or professor, specifically, who contributed to the participants' math low points. This typically involved a teacher who created a bad experience for the participant through ineffective teaching or negative interpersonal interactions.

Mentions of ineffective teaching were particularly prominent for High MSC participants. For instance, Ian discussed how his teacher provided material but did not explain it well: "In my first semester of college, my first math teacher was horrendous. She did not teach, rather just gave us notes and gave us brief explanations of each topic. It was horrible that our first test average was a 66 percent…" Shayla recalled a teacher who seemed uninterested in teaching the material, explaining that "the teacher was not helpful … he would explain the bare minimum then sit at his desk for the rest of the class period." Other participants expressed similar sentiments about teachers who they felt were ineffective, with statements such as, "the way [the teacher] taught made it hard to learn the material," and "the teacher didn't teach very well." Relatively few High MSC participants recalled negative interpersonal interactions with their teachers, but those that did typically recalled experiences that related back to their grades or status in comparison to others. For instance, Talia recalled how the consequences of not being recommended for an advanced math class in elementary school followed her throughout the rest of her education:

> "… Believing that I was among the smartest students in my grade, I thought I would be recommended for the algebra class. Sadly I wasn't, but many of my friends were. Because of this, I felt particularly unintelligent … This day has stuck with me all this time because all throughout middle school and high school I was one grade level of math behind many of my close friends, but I shouldn't have been…"

Another participant recalled a negative interaction when a teacher accused her of cheating, "… [the teacher] made a point to come over to my desk and write a large zero on the top of my quiz. I was humiliated and confused as to what I had done to deserve that, so I asked my teacher "I'm confused, why did I get a zero?" And she accused me of cheating in front of the entire class.".

Whereas High MSC participants mentioned ineffective teaching more often than negative interactions with their teachers, the opposite was true for Low MSC participants. The few Low MSC participants who did mention ineffective teaching had similar sentiments as the High MSC participants. However, in contrast to High MSC participants, Low MSC participants who mentioned negative interpersonal interactions seemed to recall more personally distressing scenarios that also included references to *negative affective experiences*. These often included being made to feel "stupid" or feeling humiliated by their teacher. For instance, Angela recalled being chastised by the professor in front of her class:

> "… I was called on to answer a math question on our homework. Although I got the answer correct, I didn't read the problem the way the professor wanted me to and although I don't think he meant to, I felt like he humiliated me in front of my whole class. He basically said that me not knowing how to read the math problem is the fault in the American education system, like I'm the epitome of what's wrong with this country's education."

Another participant, James, recalled a teacher who not only singled him out, but also laughed at him for not knowing an answer:

> "The teacher, who had prior to this incident made fun of me in front of the class, asked me to answer the problem. I hadn't raised my hand, but I was paying attention; though still confused on how to solve the problem on the board. I don't remember exactly what the problem was, but I told my teacher that I didn't know the answer. She then told me to guess just to make it go faster. I guessed something completely wrong and my teacher laughed. Then yelled at me in front of the class. Another student yelled out the answer and she was immediately praised and I was told to be more like the other student and to get my act together. I was so humiliated that I just put my head down and cried for the rest of the day."

Unfortunately, a few Low MSC participants recalled particularly troubling experiences, such as being explicitly discouraged from pursuing math. For instance, Ava explained:

> "When I was a sophomore in high school my high school math teacher told me no matter how hard I try to be good at math I never will be, and I should just give up. I personally always knew I was never strong in math but I never believed in giving up. This moment was by far the worst because I had a mentor in my life telling me I would never be good enough."

Generally, the *teacher* theme included participants whose math low point was partially due to their math teacher. Although there was overlap between High MSC and Low MSC responses when discussing ineffective teaching, the types of experiences and emotional valence between the High MSC and Low MSC groups were notably different when discussing negative interpersonal interactions with teachers.

Unique high math self-concept themes. Narrative data from the High MSC group yielded two unique themes that were not present in the Low MSC group: *first time ability challenge* and *geometry*. The *first time ability challenge* theme included participants who mentioned that their low point originated from some struggle with the math material being taught at the time. These participants often mentioned that this experience was the first time they had ever struggled with math or academics more generally. For example, Charlotte explained her shock at failing a math test when she had performed so well in her previous math classes: "… I saw that I [failed] and my heart just dropped to my stomach. I could not believe that I had done so awful … All through high school I was amazing at math. I understood everything the first time and I would get an A on every test. Last semester I took Math 126 and I almost got 100% on every exam…" Olivia mentioned a classroom experience during which she felt lost with the math content being reviewed:

> "… I was really confused. I saw [the teacher] writing things on the board and I heard her explaining those things, but I did not know how to arrive to the same solution when doing things on my own… I had always been good at math, the lowest grade I ever earned was a B in Algebra 2, so I felt that I would somehow figure it out on my own, but that never happened."

In general, the *first time ability challenge* theme reflected participants who were surprised and frustrated by their struggles with math.

Another theme unique to the High MSC group was *geometry*. These students mentioned that their low point occurred when they were learning geometry for the first time. For instance, Josie noted, "A low point in math for me was learning geometry my first year of high school… This particular moment was bad because it was an entire class dedicated to my weakest subject in math." Another student recalled how geometry, in particular, was the first time she had struggled with math, also resulting in a code for *first time ability challenge*: "A negative experience was when I took geometry sophomore year… and I had trouble grasping the topic; I have never had a hard time with math ever and it put a strain on me that I did not like at all; I would get very emotional… because I wasn't getting it." In general, the *geometry* theme reflected participants who, despite their high math self-concept, recall geometry as their lowest point with math.

Unique low math self-concept themes. Narrative data from the Low MSC group yielded three unique themes that were not present in the high MSC group: *math aversion*, *upward comparisons*, and *critical realization*. The *math aversion* theme included participants who referenced any long-term struggle with math, lack of natural math ability, or strong dislike for math in general. For example, Mia mentioned, "I have cried in almost all of my math classes… I have always been bad at [math] and feel as if I will never improve," whereas Elizabeth succinctly stated, "Math has always been a low point for me." One student, Margaret, even referenced the memory of when she began to have trouble with math:

> "I strongly dislike math and can actually remember the exact instant in which I began to dislike the subject. It was eighth grade and I was in an advanced math; I was struggling all year, something I was not used to … although I would stay and get tutored after school, it was still not enough … I still did poorly on the exams [and] my teacher's

horrific attitude made me hate [math] and feel very discouraged in the subject."

In general, the *math aversion* theme reflects participants who have consistently struggled with math during their education, including those who reported an enduring dislike of the subject.

Narratives that included the *upward comparisons* theme referenced feelings of fear or pressure that surfaced when participants made comparisons between themselves and their peers in math. For instance, one participant recalled an experience where she compared herself to a male classmate who did not seem to work as hard in the math class: "We took the test and I felt I did okay on it, and the boy next to me who didn't even know we had a test thought it was super easy… [he] got a really high B without even studying, while on the other hand I tried understanding the topic and I got a D." Another participant, Lily, recalled an experience while taking a college math class with her friend: "…I was failing every test and quiz. This was really upsetting to me because my friend was also in the class and she seemed to understand the material enough to get C's on the tests and quizzes." In general, the *upward comparisons* theme encompassed responses where participants reflected on feeling disappointed because they were not performing as well as their peers or did not feel as capable as their peers in math.

Finally, the *critical realization* theme occurred when participants alluded to their low point experience as a critical moment in their relationship with math. These responses often mentioned some type of realization or discovery about their negative feelings towards math, or about their future with math. For instance, Audrey mentioned remembering the exact moment she began feeling anxious about math, and how this experience determined her future with math:

"I remember the exact moment I started having what is called "math anxiety." I was in the third grade, 1983, and we started having timed math tests … When the test was handed out, I specifically felt very unprepared. I wasn't ready to be timed, I was still learning, and it was upsetting to me. I knew that I would do poorly because I wasn't ready to be tested … I felt shame when I handed my test in. This was also the first time I perceived tests as being intimidating. Instead of seeing learning math as an ongoing process, learning at my own pace, it became "either you get it or you don't." I put math in the, 'it's just not for me' category."

Another participant recalled a particularly bad experience that led her to believe that she would never do well in math:

"… I felt as though I was the only student who didn't understand what was going on. Whenever we went over the homework, I always got a majority of the questions wrong and always needed help. Alongside needing help, I felt as though other people thought it was silly that I couldn't catch up… I ended up failing the first semester of the class. I was devastated [and] it was horrifying knowing that I was going to have to retake this math course. I tried getting help from my friends and those who were excelling… but I could never grasp the content. It was such a bad experience because in that moment, I labeled myself as a horrible math student and that I would never ever excel in a math course as long as I'm in school."

In general, the *critical realization* theme encompassed responses wherein Low MSC participants clearly identified their low point with math as a critical moment that determined either the expectation for a continued struggle with math, or a desire to abandon math altogether.

3.4. Mixed-methods comparative analysis

In addition to examining the variation in math low point themes, we were also interested in whether gender differences would occur in the themes used to narrate math low points (RQ2). Chi-square analyses were only completed for the themes that had adequate sample sizes and statistical power for each group. With regard to the High MSC group, chi-square analyses revealed no gender differences in mention of the *negative affective experiences* theme ($\chi^2(1, N = 80) = .083, p = .773, V = .032$), or the *first time ability challenge* theme, ($\chi^2(1, N = 80) = .000, p = 1.000, V = .000$). With regard to the Low MSC group, chi-square analyses revealed no gender differences in mention of the *negative affective experiences* theme ($\chi^2(1, N = 79) = 1.858, p = .173, V = .153$), the *math aversion* theme ($\chi^2(1, N = 79) = 1.434, p = .231, V = .135$), or the *bad grade* theme ($\chi^2(1, N = 79) = .081, p = .776, V = .032$).

In contrast to these null effects, a chi-square analysis indicated a significant gender difference in the *teacher* theme for the Low MSC group. More specifically, an inspection of standardized residuals indicated that men in the Low MSC group were significantly less likely than women in the Low MSC group to mention teachers as the source of their math low point, $\chi^2(1, N = 79) = 4.37$, $p = .037$, $V = 0.235$; a medium effect. We did not have adequate power to run exploratory chi-square analyses regarding differences in theme by racial group.

4. Discussion

Findings from the current research reveal key differences and similarities between participants with high and low math self-concept. In particular, the current findings offer insight into how narrative appraisals of a past low point in math are associated with current math self-concept and provide novel evidence to support the reciprocal relation between past achievement experiences and achievement motivation outcomes that is theorized in situated expectancy-value theory (SEVT; Eccles & Wigfield, 2020). In addition, the current study joins an emerging body of work that highlights the importance of considering individual differences in affective attributions and narrative interpretation when exploring math outcomes. Specifically, qualitative analysis of participants' narrations of a math low point provided key insight into how components of both situated expectancy-value and control-value theories play out in education, as well as how narrative interpretations vary with current math self-concept. Analyses revealed expected gender differences in levels of math self-concept and provide novel insight into how interactions with key socializers may be particularly important for girls as they learn math.

4.1. Math low points: Similar themes

Several themes were present across both the High and Low MSC groups: *bad grades*, *negative affective experiences*, and *teachers*. This suggests that certain types of math experiences are generally interpreted as unpleasant, regardless of individual math self-concept. However, despite broad thematic similarities across these low points, the way in which they were narrated often varied with level of math self-concept. For instance, participants in both groups mentioned *teachers* as key actors in their low point experiences. However, High MSC participants more often referenced ineffective teaching or a dislike for how a math course was managed as the reason for their low point. In contrast, Low MSC participants more often referenced negative interpersonal interactions with their math teachers as the key factor in their low point. This aligns with research suggesting that student perceptions of interaction quality with their math teachers are associated with their math self-concept and engagement (Perera & John, 2020; Rimm-Kaufman et al., 2014). Other qualitative research has suggested that negative affective components of teacher-student interactions in the math classroom can create interactional patterns that constrain students towards failure in math (Heyd-Metzuyanim, 2013). In other words, negative interpersonal encounters in the math classroom are likely to be more memorable and impactful for students' math self-concept. This may explain why low MSC participants often referenced negative interpersonal interactions with their math teachers as key factors in their low point stories, whereas High MSC participants did not.

Within the *bad grade* theme, participants in the High MSC group

tended to elaborate on how their performance on some math task failed to meet their own expectations. Interestingly, participants often interpreted these experiences by accepting that their own overconfidence or lack of effort resulted in a poorer grade than anticipated. On the other hand, participants in the Low MSC group more often narrated objective failures, provided more detailed descriptions of their emotions, and elaborated on the consequences of the *bad grade* experience for their future with math. The discrepancies in how similar experiences with bad grades are interpreted by participants with High and Low MSC further illustrate the importance of understanding how narrative appraisal patterns are related to academic outcomes (Eccles & Wigfield, 2020).

The responses from the Low MSC group for the *bad grade* theme also clearly depict the reciprocal relationships between self-concept, emotions, and outcomes that are theorized by the control value theory of achievement emotion (CVT; Pekrun et al., 2007). As quoted earlier, Eric's narrative described a cycle whereby his confusion with the course material led to negative emotions towards the coursework, thereby exacerbating his poor performance in the class. This only led to more confusion, negative emotions, and worse performance. Allison described a similar experience, in which she repeatedly tried, failed, and ultimately became disheartened by math, "It was eighth grade year and I was in an advanced math class, I was struggling all year … Although I would stay and get tutored after school, it still was not enough and I still did poorly on the exams. That made me hate [math] and feel very discouraged in the subject." A related pattern was also present in the *negative affective experiences* theme, where participants in the Low MSC group referenced math anxiety more often than participants in the High MSC group. This aligns with our quantitative results which suggest a negative association between math self-concept and math anxiety. Given the reciprocal relations that have been found between math self-concept, math anxiety, and math outcomes (Ahmed et al., 2012; Pekrun et al., 2007), it is unsurprising that participants with low math self-concept often detailed how their repeated experiences with math anxiety contributed to their math aversion.

4.2. Math low points: Unique themes

Although participants with both High and Low MSC reflected on some similar experiences, unique themes were also identified within each group, indicating that certain types of low point experiences may influence the development of high or low math self-concept over time. Two unique themes were identified for participants with High MSC: *First time ability challenge* and *geometry*. Interpretation patterns for these themes mirror those from other themes for High MSC participants. More specifically, participants who mentioned *first time ability challenge* and *geometry* most often referred to an experience in which their expectations for themselves were not realized. From a narrative identity standpoint, negative events require more "storytelling" than positive ones. Although some individuals may avoid processing deeply negative events, those who can engage in causal reasoning to explain the event are more likely to come to understand it as redemptive: an event in which something bad can lead to something good (McAdams, 2008). Future work should explore whether participants with high levels of math self-concept are more likely to engage in redemptive storytelling and appraise their experiences with failure as motivation to improve.

Three unique themes were identified for participants with Low MSC: *math aversion*, *upward comparisons*, and *critical realization*. The *math aversion* and *critical realization* themes likely tapped the notion of self-defining memories, or recurring experiences that trigger a re-evaluation of one's identity. For these Low MSC participants, it was often not just a single bad experience, but consistently negative experiences with math over time that led to the realization that they should no longer pursue the domain. This aligns with findings from John et al. (2020), who found that consistently negative narrations of a math experience were associated with a greater likelihood to avoid math in the future. Future research should explore how consistently bad experiences with math relate to fluctuations in math self-concept over time, and whether similarities in appraisal patterns or negative experiences with math are related to these fluctuations. In addition, while academic self-concept is an important component of both achievement and pursuit, some research suggests that the combination of self-concept and values in a domain is better predictor of pursuit (Eccles et al., 1994; Eccles & Wang, 2016; Lauermann et al., 2017). As such, future research interested in predictors of math or STEM career pursuit might consider how math narratives are related to profiles of both math self-concept and value.

The *upward comparisons* theme demonstrates the social component of self-concept, as theorized by SEVT. Within this theme, participants were primarily concerned with how their performance on a math task would compare with their peers. The mention of socializers for participants in the Low MSC group is unsurprising, given the common gender stereotypes surrounding math ability and that women were overrepresented in the Low MSC group. Because stereotypes are socially reinforced (Bigler & Liben, 2006; Koenig & Eagly, 2014; Starr & Simpkins, 2021), socializers become acutely important in the development of math self-concept and future career interests (Riegle-Crumb & Morton, 2017; Robnett & Leaper, 2012). Some prior research on social comparisons indicates that upward comparisons result in lower academic self-concept (Pulford et al., 2018; Wolff et al., 2018). This aligns with the current results, which suggest that upward social comparisons contribute to math low point experiences for students with low math self-concept. However, other research indicates that the effect of social comparisons on academic self-concept is moderated by a variety of factors including choice (whether the comparison is imposed or chosen) and approach or avoidance tendencies (see Boissicat et al., 2021 for a review). Future qualitative and mixed-methods research should more deeply explore how students with different levels of math self-concept appraise social comparison situations in math.

4.3. Gender differences: The role of teachers

Few gender differences surfaced in the themes, suggesting that despite the gender differences found in average levels of math self-concept, participants with similarly high or low levels of math self-concept tend to interpret their math low point experiences in comparable ways. However, this was not true for the *teachers* theme with low MSC participants. More specifically, men in the Low MSC group were significantly less likely to mention *teachers* than were women in the same group. This, combined with the tendency for Low MSC participants to mention negative interpersonal interactions when discussing teachers, suggests that teachers may be particularly important socializers for girls in math-specific contexts.

Given the low number of men in the low MSC group, this singular gender difference should be interpreted with caution. However, prior research does provide evidence to support this result. Indeed, prior work has found that girls are more likely to be harmed by low teacher expectations and teachers' own gender stereotypes in math than are boys (Ketenci et al., 2020; Wang, 2012), and research has consistently found that teachers' own expectations for student success can affect student self-expectancies and performance (see Wang & Degol, 2013). For example, teachers tend to believe that boys have more natural math ability than do girls (Gunderson et al., 2012; Jaremus et al., 2020; Tiedemann, 2002) and these beliefs can influence how they interact with students in the math classroom. These teachers may ask fewer questions of girls and provide less praise to girls in the math classroom, which can reinforce the stereotype that girls do not belong in math (Becker, 1981). Ava's recollection of a math teacher telling her that she would never be good at math most clearly exemplifies the impact that negative interpersonal interactions with math teachers can have on girls and women. However, participants also referenced other types of negative experiences with teachers, often noting how they were embarrassed or publicly mocked. For example, Zoe notes: "I asked the professor a question,

to which he replied in front of the entire class that I needed to use my brain and think about it for a while. I never got the answer to my question and because of that I never asked that professor anymore questions…" Savannah recalls a similar experience, in which her math teacher would "ridicule [her] in front of the class for not being able to answer questions correctly."

Person-centered work also supports the notion that teachers are critical socializers for students in math. For instance, Lazarides et al. (2020) found that students who reported higher levels of teacher fairness and friendliness in math were less likely to move out of a high math motivation profile over the course of the academic year. Another study by Lazarides et al. (2019) found that students who perceived greater teacher support were more likely to move from a medium math motivation profile to a high math motivation profile. By suggesting that positive teacher classroom behaviors can improve or sustain math motivation over time, these studies compliment the current findings, which suggest that negative teacher behaviors may be detrimental to students' math self-concept over time. Future work should continue to explore common types of teacher behaviors that might contribute to low math self-concept, in addition to understanding whether certain teacher behaviors might influence math self-concept differently for girls and boys.

4.4. Limitations

Results from the current study should be interpreted with the consideration of several limitations. First, by focusing only on participants with relatively low and high math self-concept, we were unable to gather an understanding of what math low point narratives and appraisal patterns might look like for individuals with moderate levels of math self-concept. Some person-centered work indicates that membership in profiles characterized by moderate levels of math self-concept is less stable over time (see Lazarides et al., 2020), which suggests that people with average levels of math self-concept may be most susceptible to experiences that can enhance or harm their math self-concept. As such, these individuals may benefit most from interventions designed to enhance math self-concept. The current research has illuminated how narrative appraisals of past math low points are related to high and low levels of math self-concept, and a logical next step for future research would be to explore the content of math life story narratives and appraisal patterns for individuals with moderate levels of math self-concept.

Another limitation pertains to the cutoff points used to determine membership in the High and Low MSC groups. Given the developmental nature of math self-concept, as well as the various scales used to measure the construct across the literature, there is no global determination for what constitutes "high" or "low" math self-concept. Our choice to use one standard deviation above and below the mean as the determinants for belonging to the High and Low MSC groups, respectively, was guided by our interest in understanding the similarities and differences in appraisals of math low points for participants who had higher or lower than average math self-concept. More specifically, we wanted to ensure that the measured levels self-concept for our focal groups were different enough from the sample average, while also ensuring that we did not inadvertently perform an outlier analysis, the results of which would not be generalizable. However, future mixed methods work in this domain should consider using person-centered approaches for determining typologies of math achievement motivation alongside narrative accounts of past math experiences.

It should also be noted that, given the reciprocal nature of how affective interpretations of past experiences influence achievement motivation outcomes, and that identity development is a lifelong process whereby past experiences are constantly being used to adjust and cohere a sense of self (McAdams, 2008), we cannot be sure if participants' narrative interpretations influence their current math outcomes, or if participants' current math outcomes influence how they interpret past events. Future work in this arena should employ longitudinal methods to explore the directionality of these associations. In addition to providing insight into how these past low point experiences might have influenced participants' math self-concept, the patterns present in both groups could also suggest that participants are motivated to understand their past low point experiences in ways that align with their current self-concepts (Wilson & Ross, 2003). For instance, participants with high MSC can maintain a coherent sense of self by interpreting their low point as some type of learning experience, or a past mistake that has since been corrected. In contrast, participants with low MSC can maintain their current identities by interpreting their low point as confirmation that they lack math abilities or should avoid math altogether. Indeed, despite the wealth of quantitative literature suggesting clear gender differences in math experiences and outcomes, results from the current study suggest that there are more similarities than differences in how men and women interpret their past low points in math. This may be an indicator that current levels of math self-concept influence how past events are interpreted and incorporated into the current sense of self.

Finally, the current research was focused primarily on the gender binary and excluded the three nonbinary participants from quantitative analysis due to inadequate power. However, an increasing amount of research indicates that there are more similarities between men and women then there are differences, and that the gender binary is increasingly becoming an outdated construct (see Hyde et al., 2019). If exploring gender is critical to the research, future work should, at a minimum, ensure that there is adequate statistical power to include the experiences of transgender and nonbinary individuals in all analyses.

5. Conclusion

The current study builds on an emerging body of literature that suggests narrative appraisals of past math experiences can provide a nuanced glimpse into the events that participants believe have influenced their math self-concept. Results from the current work suggest that although there are many similarities in the types of experiences participants have with math during their education, appraisal patterns and interpretations of these experiences differ with current levels of math self-concept. Indeed, participants with relatively high math self-concept often took a more positive approach to a past math low point by seeing the negative event as opportunities for growth and betterment. On the other hand, participants with relatively low math self-concept were more inclined to reference repeated negative experiences, focus more on negative emotions, and indicate how the negative events fostered an aversion to math. The current research also pinpoints certain experiences that may contribute to reduced math self-concept, such as upwards comparisons to peers in the math classroom and negative interpersonal interactions with teachers. Mixed-methods analysis revealed that bad experiences with math teachers were most memorable for girls with low math self-concept. Results from the current research clearly illuminate paths for future educational interventions. In addition, the current study underscores the value of qualitative and mixed-methods research in moving towards a more comprehensive understanding of the factors that contribute to the gender gap in math-intensive STEM careers.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

This manuscript is a component of the lead author's dissertation, and we extend our deepest gratitude to Jennifer Rennels, Paul Nelson, and Harsha Perera for their helpful feedback on earlier versions of the manuscript. We are also grateful to Lindsay Denecker and Robert Bellucci for their assistance with the qualitative coding process, as well as the students at the institution for their time and participation in the current research.

Funding Sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The authors declare no conflicts of interest.

Appendix A

Your life story about your experiences with math

Adapted from McAdams' life story prompt

Please begin by thinking about your relationship to math over the course of your life as if it were a book or novel. Imagine that the book has several main chapters that describe key scenes or experiences you have had with math. Consider your experiences with learning math, performing math, being evaluated on your math abilities, and using or doing math outside of school environments. Think about your experiences with math teachers, your friends, and peers, as well as emotions you felt while studying, being in class, or taking exams.

I would like you to focus on a few of these key scenes having to do with math that stand out over the course of your life. A key scene would be an event or specific incident that took place at a particular time and place. Consider a key scene to be a moment in your life story about math that stands out for a particular reason – perhaps because it was especially good or bad, particularly vivid, important, or memorable.

For each of the four chapters and key scenes we will consider over the next few pages of this survey, I ask that you describe in detail what happened, when and where it happened, who was involved, and what you were thinking and feeling during the event. In addition, I ask that you tell me **why you think this particular scene is important or significant in your life**. What does the scene say about you as a person? Please be specific.

1. **A math low point**[2]

Please describe a math-related scene, episode, or moment in your life that stands out as an especially negative experience. Even though this event is unpleasant, I would appreciate your providing as much detail as you can about it. What happened in the event, where and when, who was involved, and what were you thinking and feeling? Also, please say a word or two about why you think this particular moment was so bad and what the scene may say about you as a person or your life and how you relate to math.

Appendix B. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cedpsych.2022.102094.

[2] Participants also responded to four open-ended questions that were not the focus of the current research. Specifically, they described a math high point (i.e., a particularly positive experience); their experiences receiving help with math, a math turning point, and how they envision their future relationship with math.

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