Examining the Relationship Between Key Points in College Students' Drawn Life Stories in Mathematics and Their Relationship With Mathematics

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This research investigates significant moments in college students' drawn life stories in mathematics with the aim of examining implications for STEM engagement and potential reasons for gender-related differences in participation in mathematics intensive STEM fields. My research employs drawn life stories in mathematics specifically focused on students' experiences with mathematics to understand students' evolving relationships with mathematics, encompassing positive and negative experiences. Employing mixed methods analysis of visual and written mathematical narratives combined with qualitative interviews, my research explores the effectiveness of allowing participants to visualize their mathematical journeys, and quantitatively assesses the impact of recurring themes in students' drawn life stories in mathematics. This research advances our understanding of factors that influence the nature of students' relationships with mathematics, and potentially inform strategies for enhancing STEM participation and gender inclusivity, using a unique approach in mathematical narrative research.

Keywords: Mathematics Identity; STEM Participation; Gender

The United States Bureau of Labor Statistics (BLS) expects a nearly 11% increase in occupations in science, technology, engineering, and mathematics (STEM) fields from 2021 to 2031 (BLS, 2022). To ensure effective preparation of a STEM workforce that can meet these growing demands, it is necessary for both researchers and educator practitioners in STEM education to consider factors which may help students develop an interest in STEM and a belief in their STEM abilities. Thus, it is critical to avoid perpetuating historically established barriers to pursuit of STEM degrees and careers that limit the growth and diversity of the STEM workforce (Grossman & Porsche, 2014; Feder & Malcolm, 2016).

Mathematics is a useful area for this inquiry. It has been frequently referred to as a 'gatekeeper' to STEM degrees as many STEM degrees require prerequisite courses in mathematics (Bryk & Treisman, 2010; Norton et al., 2019). Additionally, most STEM fields draw on important mathematical foundations and skills. To better understand the factors that influence students' relationship to mathematics over the course of their lives, in my research I utilized an established life story narrative approach to examine students' experiences as learners of mathematics, through their early undergraduate studies (McAdams, 2001; John et al., 2020).

The process of creating and sharing life story narratives allows individuals to make sense of their past and present in a way that enables them to meaningfully anticipate the future (McAdams, 2001; John et al., 2020). Past research in mathematical narratives has been conducted primarily with preservice teachers (Towers et al., 2017). My research built on past studies by expanding the population of interest to undergraduate students more broadly as I sought to understand the factors which drive society to and away from mathematics.

A recent study in mathematical narrative research, conducted by John et al. (2020) focused on "turning points" that individuals describe in their prior histories with mathematics. In their research, they characterize turning points as either being a form of "redemption" in which individuals describe their relationship with mathematics as shifting from negative to positive, or “contamination” in which individuals describe their relationship with mathematics as shifting from positive to negative. In my research, the term “turning points” was extended to “key points” to include both turning points and instances where an individual describes an experience that makes their existing relationship with mathematics even stronger - more positive or more negative.

While there are multiple examples of studies that utilize narratives to study relationships with mathematics, there are several ways in which this area of inquiry has had shortcomings, and thus, can be improved. For instance, one key finding from John et al. (2020) was that over half (53%) of the narrative sequences described by participants were redemptive in nature. The researchers suggest that this is likely due to a prevailing master narrative in the U.S. that places a large value on redemption (John et al., 2020; Syed, Pasupathi, & McClean, 2019). It is worth considering, then, whether there are other ways of more authentically allowing students to showcase their relationship with mathematics.

Additionally, John et al. (2020) did not provide insight into the experiences or other factors that coincided with these turning points and did not assign any sort of magnitude to identify strengths of the patterns in these factors or experiences. To address this limitation, my research utilized a novel approach to narrative research, adapted from Guillaume & Kirtman (2010), in which students have the opportunity to draw their mathematical narratives. By using an open-ended drawn approach to mathematical narratives, individuals can illustrate as many key points as they can remember and the magnitude of the impact of these key points on their relationship with mathematics. The opportunity to quantify these experiences is particularly notable as most narrative research in mathematics education has been purely qualitative in nature (Towers et al., 2017).

The potential for drawn life stories in mathematics to provide insight into critical aspects of students' experiences and resulting relationships with mathematics can also be valuable for understanding factors that have historically limited the diversity and inclusivity of advanced studies and careers in mathematics and STEM. Women in the United States have historically been and continue to be underrepresented among degree recipients in math-intensive fields such as computer sciences and engineering. For instance, while women make up 51% of the overall workforce in the United States, women comprise just 26% of the mathematics and computer scientists and 16% of engineers (NCSES, 2023).

To address this underrepresentation, more efforts to understand and mitigate barriers that prohibit women from pursuing STEM pathways are needed. Thus, this research also examined what insights drawn life stories in mathematics can provide to better understand and address gender-related differences in mathematics.

The research questions for my research are as follows:

- **Research Question 1:** To what extent do recurring themes account for key points in undergraduate students' life stories in mathematics?
- **Research Question 2:** What insights can drawn life stories in mathematics provide to better understand and address gender-related differences in STEM participation?

Literature Review

Mathematics Identity

Widespread use of the term identity among researchers in multiple fields has led to variations in how it is defined (Radovic et al., 2018; Bishop, 2012; Darragh, 2016; Grootenboer et al., 2006; Grootenboer, 2013). Given the variation in its meaning, social science researchers have criticized the concept of identity for having a “slippery” and confusing nature (Wetherell, 2010; Radovic et al., 2018).

At the same time, identity has been characterized as the “missing link” between learning and its sociocultural context (Sfard & Prusak, 2005; Hong & Perez, 2024). From this perspective, learning extends beyond the construction of understanding and consists of becoming a new person with respect to cultural norms, practices, and interaction (Lave & Wenger, 1991; Wenger 1998). What students learn in and out of school extends far beyond the subject matter, students develop social and cultural perspectives on who they should be. The identities which students acquire then influence not only what students will learn, but what they will pursue and what they will become. Furthermore, as identities have been observed to potentially change over the course of students’ lives, identities are not considered to be static, but rather malleable (Andersson et al., 2015; Gonzalez et al., 2020).

Research on identity in mathematics education has been a growing field of study since the turn of the century (Radovic et al., 2018; Darragh, 2016); Simpson & Bouhafa; 2020). For the purposes of my research, I have adopted the definition of Boaler & Selling (2017, p.82) for mathematics identity as “the ways in which students think about themselves in relation to mathematics and the extent to which they have developed a commitment to, are engaged in, and see value in mathematics and in themselves as learners of mathematics". Furthermore, my research takes a Meadian conception of identity (Mead, 1913). Contrary to an Eriksonian conception of identity, which tends to view identity as singular and static, a Meadian conception suggests that a person's identity are multiple and constantly evolving (Machalow et al., 2020; Darragh, 2016; Lutovac & Kaasila, 2019).

Gender Identity Research in Mathematics Education

The exploration of gender research in mathematics education dates to the prolific work of Fennema and her colleagues in the 1970s (Fennema & Sherman, 1976; Fennema & Sherman, 1977). Research in the late 1970s following Fennema’s work would examine gender disparities in involvement and achievement in mathematics, along with investigations into potential factors that promote or hinder these differences (Leder, 2019). Fennema’s work was undoubtedly impactful on the field of mathematics education. As Walberg & Haertel (1992) reported, the Fennema & Sherman (1972) article was among the most frequently cited articles in the Social Sciences Education Index from 1966-1988.

Given that 72% of the STEM workforce are males (NCSES, 2023), research on the intersection between gender identity and mathematics identity has often focused on exploring the nature of persistent inequities in the STEM workforce. Some studies have shown that, in-general, males tend to have higher or more positive mathematics identities than females (Eccles & Wang, 2016; Lock et al., 2013; Cass et al., 2011, Nosek et al., 2002). Thus, recent research has explored a few different explanations for gendered differences in mathematics identity and in-turn gendered differences in the STEM workforce (Leder, 2019; Stoet & Geary, 2018; Rodriguez et al., 2020).

Mathematical Narrative Research

Narratives refer to the retelling of autobiographical accounts in a manner that conveys significance to the narrator and the listener (Bruner, 1990). Thus, the phrase “mathematical narratives” is often used synonymously with “mathematical autobiographies”. Mathematical narratives are a versatile data collection tool, allowing researchers to explore trends across a learners’ lifespan. As such, researchers have used mathematical narratives to explore several constructs relevant to my research including affective measures such as motivation (Harkness et al., 2007; Phelps, 2010), beliefs (Eaton et al., 2012; Dewi et al., 2022), and attitudes (Ellsworth & Buss, 2000; Russo et al., 2021).

One of the largest subfields of interest in the study of mathematical narratives has been the study of turning points, aimed at understanding the events or factors that lead to shifts in individuals' autobiographies (Towers et al., 2017). The present study uses a more inclusive term “key point” to expand the definition of turning points to also include instances where an individual describes an experience that makes their existing relationship with mathematics even stronger - more positive or more negative.

In a particularly relevant case, Guillaume & Kirtman (2010) had participants chart graphs of their attitude and achievement in mathematics, in-order to analyze the turning points that individuals drew. In their research, Guillaume & Kirtman (2010) focused on the themes that emerged from their work and particularly focused on out-of-school connections that individuals discussed. For example, they found that only 42% of individuals discussed a home connection to mathematics and that of those who *did* note a home connection to mathematics, 65% fell under school-related categories such as workbooks/flashcards and tutoring/help with homework. While this study is interesting, the graphs that individuals drew were not used to their full potential. A major benefit to having individuals draw their life stories in mathematics, which my research capitalizes on, is that drawn life stories in mathematics offer an easy way for researchers to quantify turning points. In fact, individuals noted instances of turning points on their timeline, yet Guillaume & Kirtman did not classify these events in the traditional turning points framework, instead opting to simply observe patterns among the themes. Furthermore, one can measure how far a jump or drop key points cause because of having individuals draw their mathematical timelines. My research capitalizes on this potential by both examining the key points on individuals drawn life stories in mathematics, as well as quantitatively analyzing how large of shifts these key points cause.

Methods

Participants

This research was conducted at a large university in the Southeastern United States. Participants included 254 undergraduate students pursuing a variety of majors, enrolled in either MAC 2311: Analytic Geometry and Calculus 1 or MAC 1147: Precalculus Algebra and Trigonometry. In total, 214 of the participants were enrolled in MAC 2311 and 39 were enrolled in MAC 1147. These courses serve as prerequisites and general education courses for a variety of majors and hence were strategically selected as they include students pursuing both STEM and those pursuing other fields. Conducting this survey with students currently enrolled in an undergraduate mathematics course ensured that participants’ mathematics experiences included postsecondary studies in addition to any insights they offered about their mathematical experiences in primary and secondary school.

Instrumentation

Data was collected using an instrument designed for participants to draw how their relationship to mathematics has changed over the course of their lives. An example of a completed version of this instrument in shown in Figure 1.

Participants were asked to think as far back in time as they can remember, about both in-school and out-of-school experiences, including people and experiences that have had a strong effect (either positive or negative) on their relationship to mathematics and then to map out how these experiences have shaped their relationship to mathematics over time, while labeling any key points. Participants were then asked to expand on what those key points entailed on the next page and whether they would be willing to participate in a follow-up conversation to expand on their responses.

Finally, participants were asked a few demographic questions including what gender they identify as. The research question addressing gender identity gives the options of male, female, non-binary, and genderfluid; however, it also includes an open-ended option which has been recommended in recent research (Puckett et al., 2020).

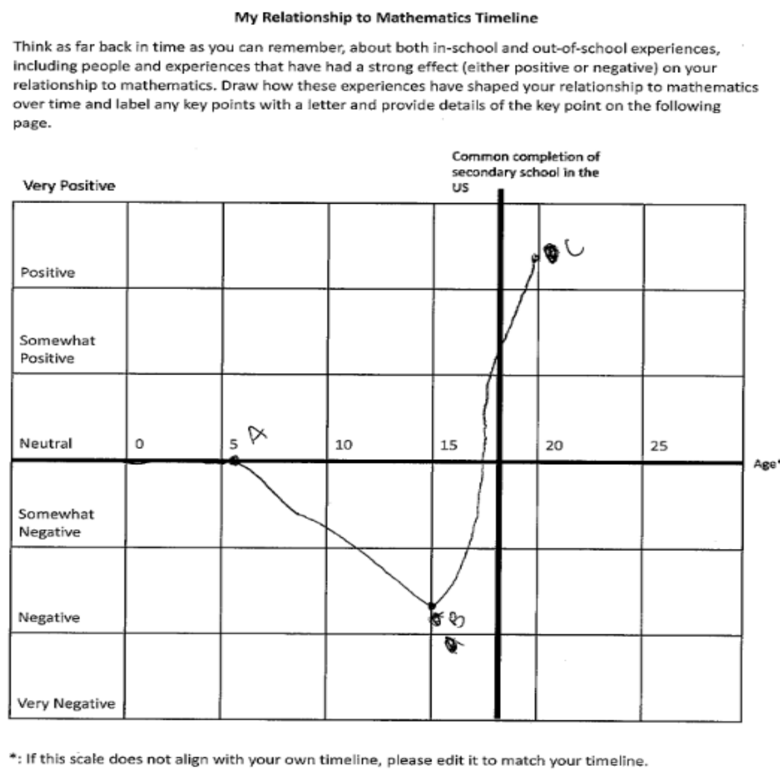

Figure 1. Example of a Drawn Life Story in Mathematics

Coding

Key points that participants described were each coded in three distinct ways. First the key points were coded deductively as either contamination, redemption, enhancement, or deterioration. These deductive codes stem from past narrative work indicating that turning points can often be seen as redemption or contamination sequences (McAdams & Bowman, 2001) and this framework has been used in the mathematical narrative space as well (John et al., 2020).

Additionally, each key point was inductively coded in two rounds, guided by the recommendations of Saldaña (2021). In the first round of coding, the descriptions of key points provided by participants were summarized. Notably, depending on the length of the participants' description of their key points, this first round of coding was not necessary in every case. The key points were then coded using pattern coding to identify emergent subthemes that underlie key points given by participants (Saldaña, 2021; Miles et al., 2014). Once subthemes were gathered, subthemes were grouped together into larger themes encompassing them. To help ensure reliability of deductive codes, the themes and subthemes were continuously refined with the assistance of another researcher.

Finally, guided by past literature illustrating a tendency for mathematical narratives to overutilize qualitative research (Towers et al., 2017), data given by participants were analyzed quantitatively using a form of magnitude coding (Saldaña, 2021). For example, in Figure 1, key point B was coded as -1.5 as it moved the respondents relationship with mathematics from neutral down 1 to somewhat negative and then half way between somewhat negative and negative. This is one of the largest potential research benefits of having participants draw their life stories in mathematics instead of verbalizing them, as drawing allows for a more detailed and consistent way of analyzing how impactful each key point was.

Results and Conclusions

First, all 254 participants' graphs were analyzed based on the structure of the graph. The graphs were coded as “Positive” if the graphs were strictly neutral or positive, “Mixed” if the graphs ever crossed the x-axis – that is, if the participants relationship from mathematics ever went from positive to negative or vice versa, and “Negative” if the graphs were ever strictly negative. Notably, the overwhelming majority of graphs changed from positive to negative or vice versa at some point (76.77%). Additionally, it is worth noting that while there were many participants (23.23%) whose graphs were strictly positive, there were 0 whose graphs were strictly negative.

Themes among Key Points

Using emergent coding, 24 subthemes were identified among the key point responses, in addition to a robust “Other” subtheme.

Magnitude coding for each key point was broken down by themes and subthemes, and then further analyzed. Each subtheme was treated separately as positive (if the key point received an “Enhancement” or “Redemption code) and negative (if the key point received a “Deterioration” or “Contamination” code). Figure 2 shows a breakdown of the positive subthemes, by both the count and the average magnitude code applied within the subtheme.

The results from the magnitude code analysis of the drawn life stories in mathematics clearly showed two recurrent subthemes that were impactful for students both in positive and negative ways: “Teacher” and “Achievement”. Beginning with the “Teacher” subtheme, participants explained a wide variety of reasons for which teachers were influential (both in positive and negative ways) on their relationship with mathematics. Some participants focused on ways in which teachers impacted their cognitive development citing reasons such as their teacher being “thorough” or “unhelpful”. However, many participants spoke about affective ways in which their teachers impacted their relationship with mathematics. For example, participants described positive impacting teachers for reasons such as them being “fun”, “caring”, and “kind” and negative impacting teachers for reasons such as them being “not welcoming” and “rude”.

Research tends to consider to what extent mathematics identity may be a predictor of future mathematics achievement (e.g. Bohrnstedt et al., 2021; Gonzalez et al., 2020); however, my research adds evidence to the inverse relationship that achievement may influence students’ mathematics identities. One explanation for this may be that grades serve as an indicator for students of the extent of their belonging within the field. As such, a positive grade may strengthen or help recover a students’ mathematics identity while a negative grade may deter or further damage students mathematics’ identity.

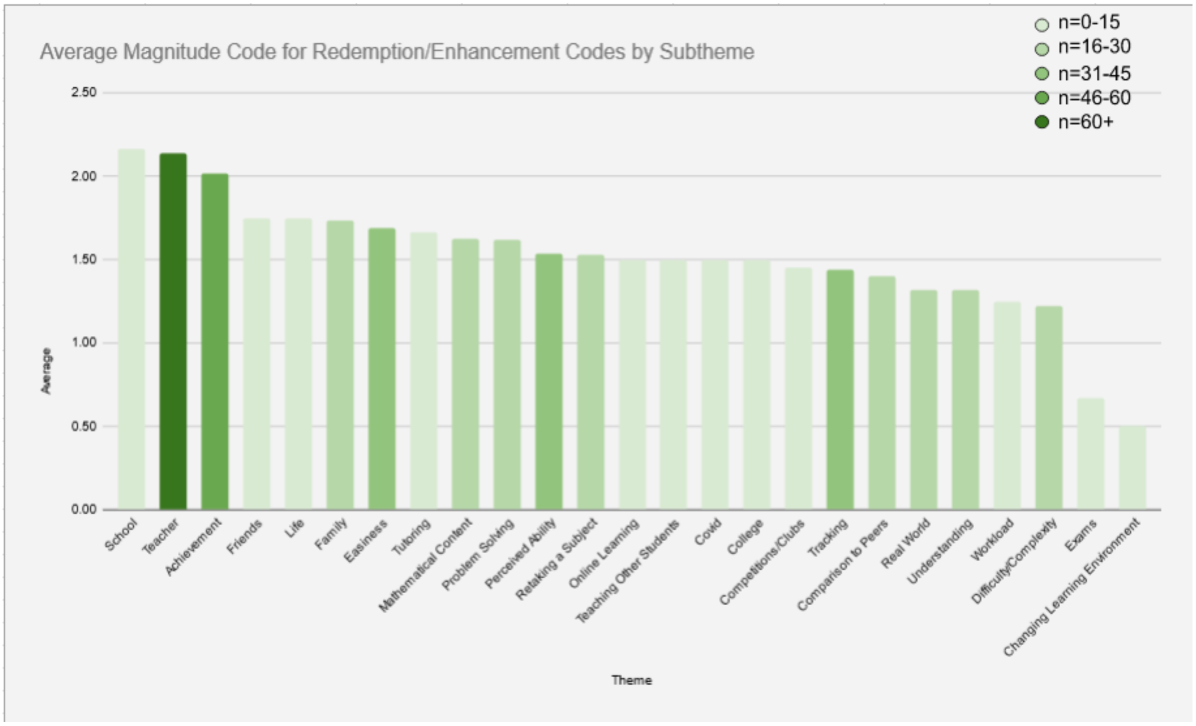

Figure 2. Average Magnitude Code for Redemption/Enhancement Codes by Subtheme.

Gendered Findings

Gender-related differences are explored in this study by examining both the prevalence and magnitude of positive (redemption or enhancement) or negative (contamination or deterioration) experiences in participants' drawn life stories in mathematics. Taking findings of both prevalence and magnitude together, with statistical significance it was shown that while positive key points were more prevalent for males than females, the positive key points that existed tended to be more impactful for females than males. This suggests that in-order to address gender-related differences in STEM participation, it may make more sense to allocate resources more towards increasing the number of positive events for female students rather than working to ensure events are more impactful for female students. For example, this finding suggests that additional celebration of achievement moments for women may not be as impactful as simply ensuring that women have more opportunities to experience positive achievement.

On the converse, insufficient evidence was found to support the notion that there was a statistically significant difference in the frequency or magnitude of negative experiences drawn on mathematical life stories between men and women. While this finding seems inconsequential, past sociological research indicates that women report more frequent negative feelings than men and that men are somewhat more likely to report that they suppress their emotions than women (Simon et al., 2004). Coupled together, the lack of statistical significance may suggest that this tool has helped male participants to more authentically share their negative emotions than a traditional survey may. There is some prior research to back this idea as drawing has shown to be a useful tool among adults as an emotional regulation technique (Drake et al., 2016; Dalebroux et al., 2008). However, in these studies drawings were used following a specific procedure with a much more in-depth protocol than my research required, so further research should be done to verify the extent to which the tool used in my research can aid in emotional regulation.

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