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Math: The Girl That All the Nerds Want

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Math: The Girl That All the Nerds Want

A thesis submitted in partial satisfaction

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in Education

by

Briana Karineh Namibia Rodriguez

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ABSTRACT OF THE THESIS

“Math: The Girl That All the Nerds Want

by

Briana Karineh Namibia Rodriguez

Master of Arts in Education
University of California, Los Angeles, 2019
Professor Jennie Katherine Grammer, Chair

Students with high math anxiety have often been characterized as low achievers and little is known about the ways math anxiety contributes to perceptions of mathematics.. In this concurrent nested mixed methods study, the personification of mathematics of 173 undergraduate students at a public university in Los Angeles was explored to examine the implicit attitudes and beliefs students have about mathematics. Additionally, the relationship between personification, math anxiety, and academic achievement were explored. Findings highlight 7 themes in the personification of mathematics across varying levels of math anxiety: *organized, rigid, useful, engaging, enigmatic, daunting,* and *thoughtful.* Results revealed a relationship between personifying math as *daunting* with math anxiety but not achievement. Differences were also observed between the way students with high and low math anxiety personify mathematics.

The thesis of Briana Karineh Namibia Rodriguez is approved.

James W. Stigler

Carola E. Suárez-Orozco

Jennie Katherine Grammer, Committee Chair

University of California, Los Angeles

2019

DEDICATION

This project is dedicated to all the children who never felt smart enough to do mathematics, the children who were told they were not smart enough to understand mathematics, and the children who persevered regardless. Thank you for teaching me how to be a resilient learner.

Thank you to my parents who taught me to never stop learning and fighting, *los quiero y admiro mucho*. Thank you to my siblings who have supported me to keep pushing forward and challenged me to always provide evidence for an argument. Thank you to my friends who never stopped cheering me to the finish line.

Thank you to the Central American community for showering me with love, healing, and support. Thank you to my Tribe for the fortitude and encouragement to follow my heart and spirit. Thank you to *mis antepasados* for providing guidance for where my path leads. Thank you to the Tongva people and ancestors for having us on your land.

Thank you to my advisors (Drs. Jennie Grammer and Gerardo Ramirez) for your mentorship and guidance. Thank you to Dr. Carola Suarez-Orozco for your warm spirit and support. Thank you to Dr. Jim Stigler for inviting me into your space and teaching me how to explore a half-baked idea.

And to the spirit of mathematics: the artist, the scientist, the healer, the elder, the timekeeper, and the friend. Thank you for walking me through the gateway to understanding the universe and the self.

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> *"Math would be a person with a very tall and intimidating frame, condescending tone and sarcastic smirk, much like a fortune 500 CEO. Everything is done their way, black or white, right or wrong. The type of person that would be a strong ally or your worst enemy."*
>
> *– White, female student*

Introduction

As shown from the quote above, students have difficulty developing a positive association (i.e., relationship) with mathematics. Oftentimes, this manifests into negative feelings about the domain of math and anxiety about performing mathematics, particularly for women (Eccles & Jacobs, 1986; Fredricks & Eccles, 2002; Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002; Wigfield & Meece, 1988) and students of color (Ho et al., 2000). Math anxiety is characterized as an unpleasant response to performing or the anticipation of performing mathematics (Beilock, Gunderson, Ramirez, & Levine, 2010). Math anxiety can prevent individuals from taking mathematics classes, inhibit their performance on future mathematics courses, and steer people away from pursuing careers and majors involving mathematics (Eccles & Jacobs, 1986). In fact, female elementary teachers who are highly math anxious have been found to shape students' own attitudes and beliefs about math (Gunderson, Ramirez, Levine, & Beilock, 2012).

Previous researchers primarily used quantitative data, such as domain specific self-report surveys, to evaluate the attitudes and beliefs students have about mathematics (Eccles & Jacobs, 1986; Fredricks & Eccles, 2002; Rice, Barth, Guadagno, Smith & McCallum, 2013). This work indicated that the attitudes and beliefs students have about mathematics can affect their math self-efficacy, math self-concept, and mathematics achievement (Gottfried, 1990; Meece, Wigfield, & Eccles, 1990). Student attitudes and beliefs can lead to difficulties recalling mathematics and have been found to significantly effect students' math achievement (Ashcraft, 2002; Ramirez, Shaw & Maloney, 2018). Other bodies of work have used qualitative data, such as short answer questionnaires, to explore students' attitudes and beliefs about mathematics (Hannula, 2002**),** but few have examined the relationships between the effects of these attitudes and beliefs on math achievement.

While previous work has been helpful in elucidating the extent to which negative math attitudes are associated with important mathematics outcomes (e.g. standardized assessments, summative assessments and course grades), these associations have not examined the relationship people have with mathematics. The relationship a person has with mathematics may hold promising insights for better understanding how students relate to the subject of mathematics and help demonstrate the variability in how students view mathematics. As such, my study seeks to explore how personification – the attribution of human characteristics to something non-human – can be used to further investigate the attitudes and beliefs students have about mathematics.

Background

Personification

Personification (anthropomorphism) is the tendency to attribute human characteristics (e.g. reasoning, feelings, physical features, and human capabilities) to non-human beings and inanimate objects (Kallery & Psillos, 2004). Ancient cultures have been personifying nature, natural phenomena, and spirits for thousands of years. People use personification to make sense of the world, aid their efficiency in learning unfamiliar objects, and satisfy their basic need for social relationships (Guthrie, 1995). There is evidence of children aged five to six using personification to generate educated guesses about the future, such as predicting the feelings of rabbits and tulips (Inagaki & Hatano, 1987). Brown and Campelo (2014) found evidence of adults' tendency to personify places (e.g. Toronto [Queen City] and Venice [Queen of the Adriatic]) and notes its possible utility in marketing of urban spaces.

Personification is also found in science, technology engineering, and mathematics (STEM) fields (see Taber & Watts, 1996; Zazkis, 2015). Teachers and students use personification to explain the nature of matter in science classes. For example, a teacher might describe two particles were described as "always [repelling] each other because they… just don't like each other" and the element fluorine was seen as "being greedy trying to grab two electrons" (Taber & Watts, 1996). Amazon's "Alexa" and Apple's "Siri" seek to tap into our basic need for social relationship through personification of technology. Additionally, Mayor and Estrella (2014) conducted a study on the benefits of using multimedia instruction involving graphics with emotional design (i.e. researchers redesigned standard human cell and viral cell graphics to have human-like features), which resulted in the emotional design group outperforming on a learning test than the control group (the non-personification group). In addition to personifying specific

STEM concepts, researchers have asked participants to personify fields of study such as mathematics. For example, Zazkis (2015) conducted a study eliciting personification by asking preservice teachers to write character summaries for mathematics as a person. Because in this example personification was used as an instructional tool to help preservice teachers be more conscious of their relationship with mathematics, it is still unclear how learners personify mathematics.

Personification may aid in facilitating reflection about our own relationships to mathematics (Zazkis, 2015), and could also provide researchers and educators with insight into the attitudes and beliefs learners have about mathematics. In one case study exploring students' attitudes towards mathematics, Hannula (2002) shared that one middle school student, Rita, stated math was "nicer in elementary school than it is in secondary school…" Through her use of personification, we can see Rita's belief that higher-level mathematics is more difficult to understand. It is important to note that this belief is not unique to Rita and is often shared by many students who are required to take mathematics courses to fulfill secondary or general education requirements. Although Hannula's study did not focus on the personification of mathematics, it provides evidence that students naturally use personification to describe their attitudes and beliefs about mathematics.

Importantly, personification could be used to understand the variability in students with math anxiety. While studies have shown that high math anxiety is negatively correlated with low mathematics achievement (Norwood, 1994; Wu, Amin, Barth, Malcarne, & Menon, 2012), there is also evidence of students with high math anxiety (e.g. highly anxious about performing mathematics in the classroom) being high achievers (Satake & Amato, 1995; Foley, Herts, Borgonovi, Guerriero, Levine & Beilock, 2017). Personification of mathematics could reveal how students with high math anxiety attribute mathematics with both positive and negative characteristics. Thus, these characteristics about mathematics could help explain that even students with high math anxiety are successful. Moreover, students' responses could help researchers and teachers determine appropriate interventions to target math anxious behaviors, specifically for low achieving students . However, before doing so, we must first understand how students personify mathematics. Thus, the purpose of this study to explore how students personify mathematics.

Math Anxiety and Math Achievement

Math anxiety is the feeling of tension, apprehension, and fear of performing mathematics (Richardson & Suinn, 1972). Performing mathematics has previously been measured by asking students to solve math problems in standardized tests, summative class assessments, and for course grades (Eccles & Jacobs, 1986; Schoenfeld, 1989; Beilock, Gunderson, Ramirez, & Levine, 2010; Ramirez, Shaw & Maloney, 2018). When a person has math anxiety, they can exhibit specific behaviors such as avoidance of work at home or in school, temper tantrums, crying, cursing, and even silence. Students with math anxiety across all ages often express feeling overwhelmed, frustrated, doubtful, and sad. Gierl and Bisanz (1995) observed math anxiety in children as young as third grade; they found two distinct forms of math anxiety in grades three and six: test anxiety and problem-solving anxiety. Children's math anxiety has been speculated to relate to both parental (Gunderson et al., 2012) and teacher math anxiety (Beilock, Gunderson, Ramirez, & Levine, 2010) suggesting that important socializers are sources of a child's math anxiety.

Math anxiety has also been found in middle school and high school adolescents. Wigfield and Meece's (1988) longitudinal study examining children's beliefs, attitudes and values about mathematics found the same components of math anxiety in both younger and older children and found that students who value mathematics and put forth effort into learning it are more concerned with performing well in mathematics. Evidence has suggested that female students (Eccles & Jacobs, 1986; Fredricks & Eccles, 2002; Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002; Wigfield & Meece, 1988) are more likely to develop math anxiety than male students, and students of color (Ho et al., 2000).

Given that math anxiety is a common phenomenon, it is important to understand why people across all groups experience it in the first place. There are three perspectives about the origins of math anxiety (Ramirez et al., 2018). The reduced competency perspective argues that math anxiety is actually the *outcome* of poor math ability. Second, the disruption of working memory theory argues that math anxiety is the *causes* of poor mathematics performance because of the cognitive overload of the working memory. Finally, the interpretation theory argues that math anxiety is determined by how people interpret their previous math experiences and outcomes. The current study seeks to build upon the interpretation theory by investigating whether the attitudes and beliefs about mathematics vary within students with math anxiety.

Self-Efficacy and Math Achievement

Self-efficacy is a person's beliefs in one's capability to execute an action required to produce given attainments (Bandura, 1997; Bong & Skaalvik, 2003). It is concerned with an assessment a person has about accomplishing a task or problem in the future with whatever skills and abilities they possess. According to Bandura (1986), self-efficacy is more predictive of future performance than confidence in learning mathematics. Math self-efficacy has been found in children as young as 11 years old (Bandura, Barbaranelli, Caprara, & Pastorelli, 2001) and across diverse racial-ethnic backgrounds (Bong, 1999).

Higher levels of math self-efficacy (i.e. they have a greater expectation for success in mathematics) are associated with individuals pursuing more career options and increased probability in staying in more challenging careers (Bandura, 1997). Self-efficacy has been found to predict mathematics achievement in both White and Latino students (Stevens, Olivarez, Lan, & Tallent-Runnels, 2004).

Math Self-Concept and Math Achievement

Math self-concept is a person's knowledge and perceptions about themselves as mathematicians (Bong & Skaalvik, 2003). Self-concept differs from self-efficacy in that self-efficacy is a judgement of one's own ability to implement future behaviors in specific situations, while self-concept is a judgement made about past situations (Pajares & Miller, 1994). According to Eccles and colleagues (1984), this knowledge and perception of self is influenced by a psychological and socialization component positing that a person's expectations for success are not only influenced by their estimates of difficulty of a task, but also by other people's perceptions of their abilities.

Math self-concept is formed as early as grade four (Marsh & Shavelson, 1985) and will form in children with learning disabilities (Kloomok & Cosden, 1994). When students have a higher mathematics self-concept, they are more likely to self-report higher grades (Brown & Leaper, 2010). In addition, there is also evidence demonstrating self-concept as a predictor for math achievement (Else-Quest, Mineo, & Higgins, 2013; Ryan & Pintrich, 1997). These patterns of association vary along important individual characteristics; for example, this higher perceived competency was truer for European American girls than Latina girls.

The Measurements of Attitudes and Beliefs

The most common way to measure students' attitudes and beliefs about mathematics (e.g. math anxiety) is by asking students to choose between a closed set of responses (e.g. on a Likert scale), though these surveys can vary between researchers. For example, Eccles and Jacobs (1986) used questionnaires to determine beliefs (e.g. value of mathematics courses) of students in seventh through ninth grade to examine sex differences in students' attitudes towards mathematics. Wigfield and Meece (1988) used the Student Attitude Questionnaire (SAQ), consisting of eleven items, to assess students' beliefs about mathematics (e.g. students' expectations for success, incentive values, perceived ability, perceived effort, and perceived task difficulty). They also developed a Math Anxiety Rating scale adapted from existing literature at the time, consisting of twenty-two items, to assess different dimensions of affective reactions to mathematics (e.g. dislike, discomfort, worry, fear, dread, etc.). Although these measures allowed researchers to target domain specific beliefs and attitudes about mathematics, student responses were limited to the constructs given to them. Because students were not given the option to freely express their own thoughts and feelings, the researchers were still unable to understand the source of students' mathematics anxiety.

In more recent work, Vinson (2001) used the *Mathematics Anxiety Rating Scale* (MARS; Richardson & Suinn, 1972), a 98 item, self-rating scale to measure attitudes preservice teachers have towards mathematics (e.g. math anxiety) to examine the effectiveness of a mathematics methods course emphasizing manipulatives in changing these attitudes. Furthermore, Rice and colleagues (2013) used another Likert-type scale to measure affect (e.g. "Doing math makes me nervous") to investigate the relationship between social support, self-efficacy, and attitude in mathematics. This style of measurement has been used for the last 70 years and has helped us understand math anxiety as more than just an individual experience, but it has not given a full picture of attitudes and beliefs.

Students' attitudes and beliefs have also been measured with qualitative responses. Previously, Picture-Story exercises, like the Thematic Apperception Test (Wyatt, 1947), were employed in experiments wherein researchers would provide participants with four to six pictures depicting a variety of social settings and ask them to write an imaginative story about the picture. Because pictures do not provide verbal cues, coded stories are assumed to demonstrate implicit motives such as emotions and beliefs (Slabbinck, De Houwer, & Kevhove, 2011). Additionally, the Pictorial Attitude Implicit Association Test (Slabbnick et al., 2011) has been used to capture attitudes towards pictures relating to implicit motives. These measures have been frequently used over the years in psychological research, but none have examined the implicit attitudes and beliefs students have about mathematics.

One paradigm for qualitatively understanding students' beliefs about science is the Draw a Scientist Test (DAST) (Finson, 2002) which seeks to understand the stereotypical perception of scientists. Studies using this paradigm have revealed that children in primary and secondary education perceive a scientist to be an elderly or middle-aged male in a white coat with glasses (Finson, 2002). The DAST was then adopted to measure students' stereotypical perception of engineers (Draw an Engineer Test; Knight & Cunningham, 2004) through qualitative and quantitative responses, revealing that most undergraduates perceive engineers to be a male who builds with tools (e.g. workbench, safety glasses, and heavy machinery). These measures provide great insight into people's beliefs about who does science and engineering, but does not give us insight into what students believe about the subjects themselves.

There are also studies that have examined what students believe about mathematics through personification. Hannula (2002) captured in her case study how one student, Rita's, attitude towards mathematics changed. In elementary school, she had an expectation of unpleasant emotions when doing mathematics, but spoke about positive experiences; in secondary school, Rita expressed that "mathematics is quite nice" after having done well on a mathematics test. Unfortunately, this study does not give us insight on the attitudes and beliefs of students who do not have a negative affective reaction when it comes to mathematics. In contrast, studies eliciting descriptions of personification provide us with an insight into how teachers view their relationship with mathematics, whether this relationship is positive, and the love/hate relationship often felt when you like a subject that is challenging to understand (see Zazkis, 2015). Though Zazkis (2015) provides us with a foundation for how teachers personify mathematics, we must also recognize that teachers were students before they were teachers. Thus, it is important to study the personification of mathematics from the perspective of learners.

Current Study

To accomplish the aims of this study, a concurrent nested mixed methods design was appropriate because the data was collected simultaneously and the qualitative data was transformed to integrate quantitative analyses (Clark & Creswell, 2008, p. 184 – 185). The aim of this study is to thus explore the personification of mathematics, and its relationship to math anxiety and academic achievement. The first phase of the study used a grounded theory approach (Strauss & Corbin, 1998) to explore personification of mathematics for undergraduates entering a statistics course. The qualitative exploration of personification of mathematics utilized survey data collected from an undergraduate statistics course where students were asked to personify mathematics and respond to questions about their self-concept, self-efficacy, and math anxiety prior to beginning their statistics course. The qualitative data was then transformed into quantitative data: coded categories of personification. The second phase of the study, the quantitative exploration of personification, examined relationships between coded categories with self-reported math anxiety and achievement in the course. The research questions guiding my study are:

Qualitative Research Question 1: How do undergraduates personify mathematics?

Mixed Methods Research Question 2: Is there a relationship between student personification of mathematics and math anxiety?

Quantitative Research Question 3: Is there a relationship between student personification of mathematics and math achievement?

Method

Participants

Participants were psychology majors at a four-year university in Los Angeles in spring of 2018. Demographic characteristics of the participants can be found in Table 1.

Table 1. *Demographic Characteristics of Participants.*

	White		Asian		Latino		African-American		Other	
Demographics	n	%	n	%	n	%	n	%	n	%
Sex										
Female	40	83.33	54	85.71	32	80.00	10	90.91	7	63.64
Male	8	16.67	9	14.29	8	20.00	0	0	4	36.36
Declined to state	0	0	0	0	0	0	1	9.09	0	0
Year in school										
One	3	6.25	11	17.46	2	5.00	0	0	1	9.09
Two	39	81.25	47	74.60	35	87.50	10	90.91	8	72.73
Three	6	12.50	5	7.94	3	7.50	1	9.09	2	18.18
Total	48		63		40		11		11	

Procedures

Context. As part of a larger research and design study to improve an introductory statistics course, 186 students were asked to fill out a survey prior to beginning the course in spring of 2018. This survey included questions on demographic information, such as sex, race, and year of school at the university, as well as measures for the personification of mathematics, math anxiety, math self-concept, and math self-efficacy. Students then took a 10-week course on basic statistics and data analysis with an emphasis on its application to research in psychology. The goal for the course was for students to understand concepts on descriptive and inferential statistics, to use them in new situations, to be able to do basic data analysis using R statistical programming language, and to be prepared cognitively and emotionally to learn more advanced techniques in the future. Students majoring in psychology must complete the course with a C- or better to remain in their degree program. Students who were missing any of the measures below were excluded from the final data analysis.

Measures

Personification. After answering questions about their demographics, participants were asked to answer the following prompt, "Imagine Math was a person. Describe the kind of person Math would be." Students were directed to write as much as they desired, and no time limits were imposed on this prompt.

Math Anxiety. Participants were also asked to self-report their math anxiety using items from the Short Math Anxiety Rating Scale (Alexander & Martay, 1989) that asked them to rate how anxious they feel about mathematics (e.g. "In general I tend to feel very anxious about mathematics" and "I am feeling very anxious about being able to master the material in [this course]." Responses ranged from 0, strongly disagree; 1, disagree; 2, neither agree or disagree; 3, agree; 4, strongly agree. Possible range of scores for math anxiety rating (MAR) was from 0 to 8. Based on previous work (e.g. Eccles, Adler, & Meece, 1984), terciles were participants who scored 3 or below (i.e. they mostly answered with 0s and 1s on the scale) were classified as low math anxiety (LMA), those who scored 6 or more (i.e. they answered with 3s and 4s) were classified as high math anxiety (HMA) and those who scored 4 and 5 were classified as moderate math anxiety (MMA).

Math Self-Concept. Consistent with Eccles, Adler, and Meece (1984), students were asked, "In general, I consider myself to be very High in Math Ability," and rate their response (0, strongly disagree; 1, disagree; 2, neither agree or disagree; 3, agree; 4, strongly agree).

Math Self-Efficacy. Participants were asked to predict what letter grade they might earn in the course (e.g. A+ and A, 4.0; A-, 3.7; B+, 3.3; B, 3.0; B-, 2.7; C+, 2.3).

Achievement. Student achievement was measured using the average of the 5 quizzes (QuizSum) taken every 2 weeks throughout the 10-week course, with each quiz being out of 100 points and cumulative. In addition, students were assessed using a final exam, graded out of 100 points and cumulative. QuizSum and FinalExam were highly correlated ($r(170) = .75$, $p < .01$). As a result, achievement was measured as the average between the QuizSum and the final exam score.

Data Analysis

The final sample consisted of 173 of 186 participants. Thirteen participants were not included in the final sample because nine students did not complete the survey, one student did not answer the question about self-concept, and three students did not take the final exam. IBM SPSS software, version 25, was used to conduct all statistical analyses. Table 2 demonstrates the means and standard deviations for all variables calculated for the total sample of 173.

Table 2. *Means and standard deviations of Math Anxiety, Self-Concept, Self-Efficacy and Achievement.*

	Mean	Standard Deviation	Minimum	Maximum
Math Anxiety (MAR)	4.73	2.12	0	8
Self-concept	2.13	1.12	0	4
Self-Efficacy	3.63	.48	2	4
Achievement	86.25	10.18	24.06	98.75

Descriptive Statistics.

Normality. Figure 1 represents the normal distribution of math anxiety (MAR) and Figure 2 represents the normal distribution of achievement.

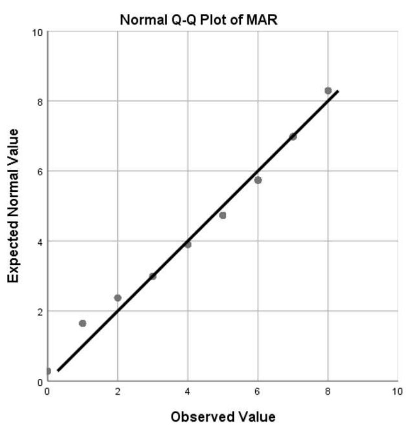


Figure 1. Math Anxiety Normality.

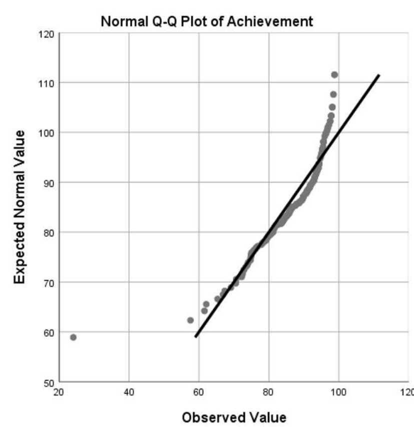


Figure 2. Achievement Normality.

These graphs demonstrate a relatively normal distribution of both MAR and achievement amongst the sample.

Pearson correlations (Table 3) were examined to look at the relationship between math anxiety, self-concept, self-efficacy, and achievement.

Table 3. *Pearson correlations of Math Anxiety, Self-Concept, Self-Efficacy and Achievement.*

	Math Anxiety	Self-Concept	Self-Efficacy	Achievement
Math Anxiety (MAR)	--	-.596**	-.386**	-.220**
Self-Concept	-.596**	--	.259**	.179*
Self-Efficacy	-.386**	.259**	--	.461**
Achievement	-.220**	.179*	.461**	--

** Correlation is significant at the .01 level.

* Correlation is significant at the .05 level.

Qualitative Research Question 1: *How do undergraduates personify mathematics?*

Guided by a grounded theory approach (Strauss & Corbin, 1998), open coding was used to develop codes based on student responses. Following the analytical procedures of Strauss and Corbin (1998), open coding was used after analyzing each response individually, to identify, name, and categorize phenomena in the personification responses. Data were initially broken down by asking, "What were the main themes of this response?" Afterwards, data were compared, and similar themes were grouped together and given the same conceptual category. Axial coding processes were then used to develop connections between a category and its subcategories, resulting in thirteen codes. Using participants' responses, definitions were created for each code. Through initial collaboration with undergraduate students in non-STEM majors (the data coders), the number was reduced to nine codes: *logical, organized, rigid, useful, engaging, mundane, enigmatic, daunting, and thoughtful.*

After further analyses, further consolidation of codes was conducted. Specifically, the code *Logical* was collapsed into *Organized*. This decision was made because coders had difficulty deciphering the difference between the theoretical concepts of the two and because a chi-squared test demonstrated a statistically significant relationship, χ^2 $(1, N = 173) = 5.088$, $p = 0.024$ at a significance level of $\alpha \leq 0.05$. Similarly, code *Rigid* was collapsed into *Mundane* and a chi-squared test demonstrated a statistically significant relationship as well, χ^2 $(1, N = 173) = 12.447, p = 0.001$ at a significance level of $\alpha \leq 0.05$. Thus, *Logical* codes were collapsed into *Organized*, and *Mundane* was collapsed into *Rigid*.

While other codes also demonstrated a statistically significant chi-squared test results, coders had not recognized them as being theoretically associated. Table 4 below demonstrates the codes developed, the definition, and its frequency. Personification responses could be coded for more than one category (i.e. codes were not mutually exclusive). Sixteen of the 173 participants were not coded for any of the categories and the percent of agreement between the final coder and the investigator was 128 out of 173 (73.98%).

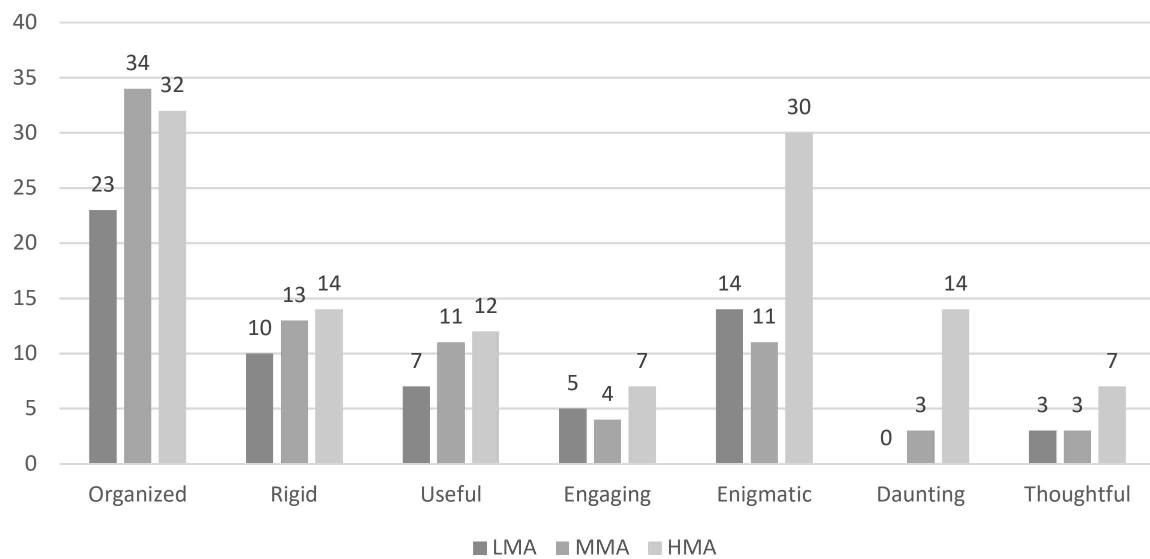
Table 4. *Definition of codes and its frequency.*

Category	Definition	Frequency	
Organized	Someone who is deliberately efficient and detail oriented. They think objectively and logically, and they are methodical and systematic.	Present Absent	89 84
Rigid	Someone who follows the rules and is inflexible. Someone who is emotionless and dull. They only see things in one way.	Present Absent	37 136
Useful	Someone who is helpful and solution driven. They are reliable and determined to find the correct answer.	Present Absent	30 143
Engaging	Someone who causes great surprise and sudden wonder. They are attractive and enchanting.	Present Absent	16 157
Enigmatic	Someone who is hard to figure out. They are complicated and confusing. They can be difficult to understand.	Present Absent	55 118

Daunting	Someone who is scary and intimidating. They are the source of anxiety and fear.	Present Absent	17 156
Thoughtful	Someone who is introspective. They are contemplative and reflective.	Present Absent	13 160

Organized and *Enigmatic* were the two codes with the highest frequency, *Rigid* and *Useful* with moderate frequency, and *Engaging*, *Daunting* and *Thoughtful* with the lowest frequency. Table 5 demonstrates the frequency math anxiety level by personification code.

Table 5. *Frequency of MAR for each personification code.*



Mixed Methods Research Question 2: *Is there a relationship between how students personify mathematics and achievement?*

Data analysis for this research question allowed for the integration of both the quantitative and qualitative data. Once the personification categories were created, a dummy variable was created for each category. Then, a one-way, between-subjects analysis of variance

(ANOVA) was conducted to compare mean differences in math anxiety by each personification code. In the analysis, each personification code was used as an independent variable and the dependent variable was math anxiety. Because some student responses were coded for multiple personification categories, each code was analyzed separately to compare students who were coded for a personification category (e.g. *organized*) to those who were not coded for that category (i.e. some students were included across many individual tests). It was hypothesized that believing mathematics is *daunting* would significantly impact math anxiety.

To explore the differences in personification between students with high and low math anxiety, students' qualitative responses were examined for differences language use (e.g. lexical choice). Differences are reported with examples from the data.

Quantitative Research Question 3: *Is there a relationship between how students personify mathematics and achievement?*

A one-way, between subjects ANOVA was conducted to compare mean differences in achievement by each personification.. Additionally, a one-way ANCOVA was calculated to examine the effect of personification on achievement, controlling for math anxiety. It was hypothesized that believing mathematics was *daunting* will would be significantly associated with math achievement.

Results

To provide context about the students in this study, the sample will be characterized by a series of descriptive analyses of achievement by race-ethnicity and sex. Following these analyses, each research question will be addressed separately.

Descriptive Statistics. A one-way between subjects analysis of variance (ANOVA) demonstrated no statistically significant mean differences in math anxiety by race-ethnicity at an alpha level of .05 [$F(4, 168) = 1.058, p = .379$. Additionally, a one-way between-subjects ANOVA demonstrated a statistically significant mean difference in achievement by race-ethnicity at an alpha level of .05 [$F(4, 168) = 10.141, p = .000$. A post hoc test examining the mean differences between each racial-ethnic category (Table 6) using a Bonferroni correction revealed the differences in achievement.

Table 6. *Mean differences in Achievement by Race-Ethnicity.*

		1	2	3	4	5
1. White	Mean difference	--	2.721	9.795	14.491	1.741
$M = 90.542$	Significance		.050*	.000*	.000*	.410
2. Asian	Mean difference		--	7.074	11.769	-.981
$M = 87.820$	Significance			.001*	.000*	.964
3. Latino	Mean difference			--	4.696	-8.054
$M = 80.745$	Significance				.296	.063
4. AfrAmer	Mean difference				--	-12.750
$M = 76.051$	Significance					.003*
5. Other	Mean difference					--
$M = 88.801$	Significance					

$*p < .05$

Specifically, White students had the highest achievement score in the course and there was a statistically significant difference between White students and Asian, Latino and African American students, however there was no statistically significant difference between White students and Other students. Asian students also had higher achievement scores than Latino and African American students, with mean differences in achievement being statistically significant. Latino students also had higher achievement scores than African American students, with the mean difference in achievement being statistically significant.

Lastly, the independent sample t-tests demonstrated there was a statistically significant difference in mean math anxiety between males and females (Table 7) with female students self-reporting higher math anxiety than male students. No differences in achievement were observed as a function of sex. Although male students had higher achievement scores, this difference was not statistically significant. It is important to note that African American students had the lowest achievement scores of all the racial-ethnic groups, in addition to having the highest math anxiety (see Table 7).

Table 7. *Mean differences in Achievement and Math Anxiety by sex.*

	Female M (SD)	Male M (SD)	Sig.
Math Anxiety	4.92 (2.044)	3.72 (2.218)	.005*
Achievement	86.650 (9.009)	84.776 (14.666)	.366

$*p < .05$

Qualitative Research Question 1: *How do undergraduates personify mathematics?*

In analyzing the data from the personification responses, 7 themes emerged relating to the perceptions and beliefs students had about mathematics: mathematics as a person being *organized*, *rigid*, *useful*, *engaging*, *enigmatic*, *daunting*, and *thoughtful*.

Organized. Participants who personified mathematics as *organized* described it as being logical, smart, and introverted. In addition, participants described mathematics as having a “type A” personality, “wears glasses instead of contacts because they are more reliable” and is of no gender (i.e. 87.5% of participants who described mathematics as *organized* do not assign mathematics a gender in their responses). One participant described mathematics as such:

> *Someone really smart, quiet, and always thinking. Math would probably be an introvert, but Math would also always have some really insightful things to say and a witty/"punny" sense of humor to match. I think Math would also be quite practical and a good planner.*

Rigid. Participants who personified mathematics as *rigid* described it as being a “stickler for rules”, strict, and strait-laced. In addition, participants also described mathematics as being robotic, “not a very charming nerd”, and stoic. One participant described mathematics in the following way:

> *Math person would be meticulous and precise in all of their everyday actions. Math person would have a routinized schedule where they would not want to stray away from.*

Useful. Participants who personified mathematics as *useful* described it as loving to find problems and solutions, good at problem solving, and “asks questions others won’t, like ‘why’ or ‘how’”. Additionally, participants also described mathematics as the “go-to” person for helping their classmates or friends with problems, having “insightful things to say”, helping us understand the world better, and practical. An example of a participant describing mathematics as *useful* is found below.

> *Math is a beautiful person. Most people don't understand how beautiful they are because whenever people try to introduce Math to others they often don't explain Math's personality and intricacies quite well. Math is easily and beautifully understood if people took the time to understand them. Math is a great influencer in the world around us. You may not think it, but they are always there. Math helps us understand the world better. Math is full of problems that's for sure, but like all problems that Math brings, they are solvable. I will admit that I have struggled with understanding Math and the crazy problems that they come with, but Math will always be beautiful to me.*

Engaging. Participants who personified mathematics as *engaging* described it as being interesting to listen to, spontaneously and unexpectedly fun, and liking to stimulate or trick others' minds. The following example response is of a participant describing mathematics as *engaging*.

> *Math would be a mysterious yet alluring individual. They would be someone that initially didn't seem friendly but turned out to be very kind. They are unaware of how brilliant they are and forget that other don't see the world like they do. It can be frustrating to interact with Math because they unintentionally make you feel like you know nothing compared to their knowledge.*

Enigmatic. Participants who personified mathematics as *enigmatic* described it as being a complex, confusing person who is hard to get along with. Additionally, participants also described mathematics as complicated, challenging, and an old man. One participant described mathematics in the following way:

> *Math would be the person who studies all night, who barely sleeps and would talk really fast. They would know odd things but not know how to explain where they got the information. They would be confusing to talk to and somewhat deceiving because there would be different ways of figuring them out, sort of a multiple personality kind of person.*

Daunting. Participants who personified mathematics as *daunting* described it as being an awful, horrible conniving person; a tall, imposing figure; and Satan. Moreover, participants described mathematics as being a middle-aged, white man, hard to approach, and a smart murderer. One participant described mathematics as such:

> *Someone I won't get along with very well, but mostly because Math scares me with impossible homework, toughly worded/graded exams, and the overall possibility of failure. Math is tall, daunting, and someone I would rather hide from than look directly in the face. Math makes me cry a lot because Math is mean.*

Thoughtful. Participants who personified mathematics as *thoughtful* described it as being quiet, introverted and inquisitive. Participants also described mathematics as asking questions such as why or how and is introspective. One example of a participant who described mathematics as thoughtful said:

> *An old, eccentric man with a long beard who is constantly writing numbers on the board, quietly muttering nonsense to himself*

Mixed Methods Research Question 2: *Is there a relationship between how students personify mathematics and achievement?*

To address this research question, each of the personification categories were transformed into dummy variables. Then, a one-way between subjects ANOVA was conducted to analyze mean differences in math anxiety. Moreover, the qualitative data was also analyzed for lexical difference between students with low math anxiety and high math anxiety,

As can be seen in Table 5, varying levels of math anxiety characterize mathematics in similar ways. More students with HMA personified mathematics as *Rigid*, *Useful*, *Engaging*, *Enigmatic*, *Daunting*, and *Thoughtful*. *Organized* is the only category for which more students with moderate math anxiety personified mathematics as such. Additionally, *Enigmatic, Daunting,* and *Thoughtful* were the categories for which more than 50% of the participants of those who personified mathematics as such were students with high math anxiety.

Organized. Math anxiety did not vary among people who personified mathematics as *organized* and not organized $[F(1, 171) = 1.547, p = .215]$. Although there was no significant difference between the math anxiety of the participants based on personifying mathematics as organized, students with high math anxiety who personified mathematics as *organized* described it as being emotionless and cold, struggling with creativity, and being a middle-aged, white male. Students with low math anxiety who personified mathematics as *organized* described it as a straight-forward person, friendly, unexpectedly fun, and a “beautiful and built person” with dark hair.

Rigid. Math anxiety did not vary among people who personified mathematics as *rigid* and not rigid [$F(1, 171) = .008, p = .927$]. Although there was no significant difference between the math anxiety of the participants based on personifying mathematics as *rigid*, students with high math anxiety who personified mathematics as *rigid* described it as being boring and not fun to be around. Students with low math anxiety who personified mathematics as *rigid* described it as not a very adventurous person but loves everyone and “tries to get people to like them”.

Useful. Math anxiety did not vary among people who personified mathematics as *useful* and not useful [$F(1, 171) = .008, p = .927$]. Although there was no significant difference between the math anxiety of the participants based on personifying mathematics as *useful*, students with high math anxiety who personified mathematics as *useful* described mathematics as being resilient, perseverant, and a leader. Students with low math anxiety who personified mathematics as *useful* described mathematics as getting along with others, dependable, and a beautiful, built person.

Engaging. Math anxiety did not vary among people who personified mathematics as *engaging* and not engaging [$F(1, 171) = .077, p = .781$]. Although there was no significant difference between the math anxiety of the participants based on personifying mathematics as *engaging*, students with high math anxiety described mathematics as being an introvert, the girl that all the nerds want, and like a drug. Students with low math anxiety who described mathematics as *engaging* described it as a beautiful and built person, and a knowledgeable old man.

Enigmatic. Math anxiety did vary among students who personified mathematics as *enigmatic* and not enigmatic [$F(1, 171) = 3.947, p = .049$]. Students with high math anxiety who personified mathematics as *enigmatic* described mathematics as being manipulative, deceiving, and an old eccentric man with a long beard quietly muttering nonsense to himself. Students with low math anxiety described mathematics as mistaken for a mean person because of his hard exterior, but if you understood the nuances of characters, you would probably fall in love; this would be a knowledgeable old man.

Daunting. Math anxiety did vary among students who personified mathematics as *daunting* and not daunting $[F(1, 171) = 8.343, p = .004]$. It is important to note there were no LMA participants who personified mathematics as *daunting*.

Thoughtful. Math anxiety did not vary among people who personified mathematics as *thoughtful* and not thoughtful, $[F(1, 170) = .047, P = .829]$. Although there was no significant difference between the math anxiety of the participants based on personifying mathematics as *thoughtful*, students with high math anxiety described mathematics as being an "old, eccentric man with a long beard who quietly mutters nonsense to himself." Students with low math anxiety who personified mathematics as *thoughtful* described mathematics as being dark-haired, wears glasses and with a high perception of the world.

Quantitative Research Question 3: *Is there a relationship between how students personify mathematics and achievement?*

The transformed dummy variables were used once more to examine the relationship between achievement scores by personification by conducting a one way ANOVA.

Organized. There was a statistically significant difference in achievement of students who personify mathematics as *organized* $(M = 87.772, SD = 8.617)$ versus those who did not $(M = 84.646, SD = 11.442)$ at an alpha level of 0.05 $[F(1, 171) = 4.150, p = 0.043]$.

Rigid. There was a statistically significant in achievement of students who personify mathematics as *rigid* ($M = 89.946, SD = 7.991$) versus those who did not ($M = 85.250, SD = 10.500$) at an alpha level of 0.05 $[F(1, 171) = 6.385, p = .012]$.

Useful. There was no statistically significant difference in achievement of students who personify mathematics as *useful* ($M = 85.644, SD = 8.633$) versus those who did not ($M = 86.382, SD = 10.498$) at an alpha level of 0.05 $[F(1, 171) = .130, p = .719]$.

Engaging. There was no statistically significant difference in achievement of students who personify mathematics as *engaging* ($M = 87.676, SD = 8.762$) versus those who did not ($M = 86.109, SD = 10.327$) at an alpha level of 0.05 $[F(1, 171) = .343, p = .559]$.

Enigmatic. There was no statistically significant difference in achievement of students who personify mathematics as *enigmatic* ($M = 85.366, SD = 8.724$) versus those who did not ($M = 86.668, SD = 10.801$) at an alpha level of 0.05 $[F(1, 171) = .612, P = .435]$.

Daunting. There was no statistically significant difference between achievement levels of students who personify mathematics as *daunting* ($M = 84.338, SD = 12.159$) versus those who did not ($M = 86.463, SD = 9.964$) at an alpha level of 0.05 $[F(1, 171) = .666, p = .415]$.

Thoughtful. There was no statistically significant difference between achievement levels of students who personify mathematics as thoughtful ($M = 86.404, SD = 10.955$) versus those who did not ($M = 86.213, SD = 10.176$) at an alpha level of 0.05 $[F1, 171) = .004, p = .949]$.

Discussion

This study aimed to examine how students personify mathematics and to explore its relationship to math anxiety and academic achievement. All students' responses contributed to the themes presented, and those themes were present across all levels of math anxiety. The study results suggest students of varying levels of math anxiety have similar attitudes and beliefs about mathematics. Personification revealed that students have that students with high and low math anxiety can have similar implicit attitudes and beliefs about mathematics.

One of the most common themes through personification revealed across anxiety level was mathematics being *Organized.* Students perceiving mathematics as *Organized* may reflect how students are taught to problem-solve in secondary education. The Common Core State Standards (CCSS; Common Core State Standards Initiative, 2013) for mathematical practice ask students to "attend to precision" and "look for and make sure of structure". As such, students are asked to use clear definitions and symbols in their work, as well as to examine problems carefully for patterns and structures to develop efficient strategies. Through the statistical analyses, it was shown that students on average who personified mathematics as *Organized* had higher achievement scores than those who did not, as well as *Rigid*. Perhaps personification is revealing to us that students are encoding these practice standards into their beliefs about mathematics, and internalizing them as important for success, regardless of whether a student is highly anxious about mathematics or not.

The second most common theme revealed through personification was mathematics being *Enigmatic*, across all anxiety levels. Students perceiving mathematics as *Enigmatic* may reflect a negative emotional valence they have developed over time, based on their previous experiences with mathematics. As a former secondary classroom teacher, this is a reflection students often make when describing mathematics. Additionally, many teachers described mathematics as the “hardest” subject to learn, which often resulted in the normalization of mathematics being “complicated” and “hard to understand”. It is possible personification reveals to us that students encode this emotional valence about mathematics and internalize it. Although perceiving mathematics as *Enigmatic* could influence math anxiety (i.e. it is consistent with previous literature on socializers as sources of mathematics; Beilock et al., 2010), it did not have a significant effect on achievement (i.e. students who wrote mathematics was complicated and confusing were more likely to have higher math anxiety, but not higher achievement). This finding suggests other factors may be involved in how students are able to succeed even when they view mathematics as confusing.

The only personification category for which only students with moderate and high math anxiety personified mathematics was *Daunting*. This finding is important in understanding the differences in the classroom experiences of students with low and high math anxiety. Not all students have positive experiences when it comes to learning mathematics, and this is a narrative we continue hearing. Although it was predicted that personifying mathematics as *Daunting* would impact achievement in the statistics course, the results of this study did not support that hypothesis. As predicted, there was a significant relationship between personifying mathematics as *Daunting* and math anxiety (i.e. if a student personified mathematics as daunting, they were more likely to have higher math anxiety). While the sample of students had a high achievement average, it will certainly be important to examine this phenomenon further amongst varying populations of achievement and developmental level.

These findings demonstrate that even when varying levels of math anxiety personify mathematics in similar ways. The study findings also point to differences in the way students with high and low math anxiety depict mathematics: students with high math anxiety tended to use more negative valence language while students with low math anxiety tended to use more positive language. Future studies should include a more extensive math anxiety rating with more questions, a more evenly distributed sample size of both men and woman, and varying levels of age. Although this study moves us forward in understanding the relationship between mathematics personification and math anxiety and achievement, it does have some limitations that should be considered. For example, future studies should also incorporate interviews with students about lexical choice and what associations those words have for them. Additionally, future studies should incorporate demographic information about whether students had the majority of the mathematics courses in the U.S. or outside of the U.S.

These findings also indicate that undergraduate students with negative attitudes and beliefs about mathematics are more likely to have higher math anxiety but having negative attitudes and beliefs about mathematics does not mean students will have low achievement. Although the average achievement scores for the sample were high, students with high math anxiety performed consistently well. This could be due to the university itself already having high student achievement, and possibly students with high math anxiety who are also high achievers developing coping mechanisms for navigating through their anxiety. It is also possible that because there were only a small number of students who personified mathematics in negative ways, there was not a big enough sample to determine whether it impacts student achievement. Future studies should include a larger sample size and a sample of students with varying levels of achievement (i.e. there is an even distribution of low achieving students as high achieving students) to better understand whether these negative attitudes and beliefs impact achievement. In addition, future analyses should examine whether students who personified mathematics as *Daunting* were also more likely to personify mathematics as another category.

Furthermore, the course was designed to focus on the conceptual understanding of statistics without having to perform mathematical procedures while still incorporating the application of mathematical thinking. It is perhaps due to the structure of the course students whose implicit beliefs about mathematics are that it is *Organized* and *Rigid* maybe have done better in the course. It would thus be important for future studies to examine the personification of students taking traditional mathematics courses and students at varying levels of developmental stages (e.g. middle and high school ages), as well as incorporating specific research questions addressing the disparity within academic achievement among diverse racial-ethnic groups.

Implications

Students with high levels of math anxiety have been argued to not be a uniform in terms of math competence (Ramirez et al., 2018). Some math anxious students have lower competence while others have high competence (Lyons & Beilock, 2011). The current study contributes to the current literature on math anxiety by including alternative measures for looking at attitudes and beliefs and looking at the individual differences within students who report high math anxiety. These individual differences could provide evidence of the interpretation framework for why high math anxiety develops and why some students still experience high mathematics achievement with high math anxiety. As we examine the similar ways in which varying levels of math anxiety personify mathematics, we can also examine the differences in how students personify mathematics; thus, possibly revealing how their interpretation of previous experiences with math have or have not affected their ability to perform mathematics. Perhaps there are strategies students develop to build resilience to being confused, in the same way we see students persevered through difficulties in learning, which is important for learning and encoding into our long-term memory (Bjork & Bjork, 2011).

Moreover, teachers could use these results to create learning experiences focused on targeting students who have high math anxiety and low mathematics achievement to close the achievement gap. While it was not addressed in this paper, the achievement gap is not only amongst students with high math anxiety, but also among students from historically marginalized communities. The experiences teachers create in their classrooms are crucial to developing as life long-learners, which affects student academic achievement. This would also mean destigmatizing students with high math anxiety as low achievers, where educators can begin to address the specific structural needs a school must provide to help students in their academic careers. Future studies could examine personification similarities and differences amongst students at the primary and secondary level of education as well. Additionally, because some of the categories present in this study are also found in the CCSS, more studies should examine whether this same trend is found in students within states that have not adopted the CCSS. This could also give us more insight as to whether students are internalizing the math practice standards themselves, or whether these themes are generally understood in the U.S. about what mathematics is and entails.

Furthermore, students' personification of mathematics could be used to create personality profiles for the personality traits described. These personality traits could then be used by both classroom teachers and parents to gain insight into a child's attitudes and beliefs about mathematics. If the child is perceiving mathematics as a threat (e.g. a "villain's sidekick"), then their math anxiety could be viewed as a behavioral response to mathematics posttraumatic stress disorder (math PTSD; i.e. a person having experienced or witnessed an event or events that involved a threat to the physical integrity of the self, which involved fear, helplessness or horror; APA definition). Currently, there is evidence math anxiety (e.g. the anticipation of doing math) is painful and activates the same regions of the brain associated with visceral threat detection, often revealing the experience of pain itself (Lyons & Beilock, 2012). Future research should address math anxiety in this way and look at the possibility of people experiencing mathematical trauma: a deeply distressing experience involving mathematics often triggered by doing mathematics in the classroom or in everyday environments. Perhaps then we can approach learning mathematics not just from a trauma-informed lens, but from a healing-centered approach.

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