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Learners' Perceptions of Elementary Math Class: A Mixed Methods Exploration

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Learners' Perceptions of Elementary Math Class: A Mixed Methods Exploration

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Approval
In the judgment of the following signatories, this Dissertation meets the academic standards that have been established for the Doctor of Philosophy degree.

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Dedication Page

To my amazing children, I hope you maintain curiosity as you continue to learn for the rest of your lives.

Acknowledgements Page

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Abstract

For social justice and change to occur in classrooms, it is necessary to consider the perspective of learners. Voices from learners around math education is limited in research, especially for younger students. This study examined math class from the perspective of elementary students, with math identity and equitable mathematics instruction as the core. A quantitative coded approach from student survey drawings (n=348) was used for comparative statistical analysis, and a qualitative observation method of categorizing attributes of interest related to emotions in the classroom was used to pull a case study of drawings for deeper analysis. Summary results from teacher surveys (n=123) were used for the triangulation of data for both the quantitative and qualitative analysis, where the results examined “what is math” and teacher’s emotions around mathematics. This study found a trend of increasing negative emotions over the years, where negative words were more prevalent and included visual depictions of emotions. Equitable instruction codes representing “collaboration” and “visuals” elements were not frequent in the drawings. There was variability from student to student, as some captured a series of nuanced experiences while others provided little detail in their drawings. Analyzing data from student drawings provides a way to humanize learners and gain more understanding of their complex selves, practically and easily to implement. Collecting student drawings can strengthen relationships, provide a reflection on the learning environment, and act as an artifact to start conversations. Drawings can also reduce the power dynamics in the form of self-expression, which addresses a key issue in researching critical pedagogies and social justice.

Table of Contents

Lists of Tables and Figures

List of Tables

List of Figures

CHAPTER ONE: Introduction

Introductory Personal Statement

"Do the best you can until you know better. Then when you know better, do better."

— Maya Angelou

Learning is a lifelong process that continues throughout an educator's career. It has taken time to develop my professional skills and integrate theory into my practice. I have learned from my students, colleagues, and experiences in schools. I must admit I am not proud of some of the interventions I provided in the past. For example, in one middle school class, I took a problem from the textbook and broke it down into the individual steps I would take to solve it. I was attempting to provide a process for English Learners (EL) to solve the problem, in reality, to get to the answer, yet I never allowed them to make sense of, or grapple with the task and enter the problem with their thinking. Now, as I reflect on instructional decisions I made, thinking they were best for students at the time, I see they were, in fact, sometimes counterproductive to my goals. I know more now, and as I continue to learn, I recognize where I fell short for some students in the past. More importantly, I recognize where I have shifted my practice as my understanding has grown in an attempt to always do better.

In various roles within different communities, I have taught multilingual learners, students with diverse abilities, and students from different cultural and economic backgrounds at schools with distinctive support systems for learners and educators. Through these experiences, I have encountered the breadth of math for students from PreK to eighth grade. This work has strengthened my appreciation for the coherence of mathematical conceptual development and recognition of the value of numeracy explorations that I have seen first-hand as essential to building strong foundational conceptual understanding. Collaborating and learning from prominent math education leaders in Vermont and across the country allowed me to grow in my thinking, reflect on my values as an educator, and take a strong stance on the necessity of rigorous quality math instruction that provides equitable access to learning for *all* students.

My experiences have also provided opportunities to stop, reflect, and wonder. Why does math instruction continue to look the way it does? What systemic elements make instruction resistant to change? Why are teachers likely to replicate their learning experiences regardless of effectiveness and their exposure to research-based practices? What can we, educators and educational leaders, change to better serve our students?

At times, I have seen that the expectations for learners are adjusted by the labels put on them; so-called "low kids" aren't provided with the same rigorous tasks and opportunities to build conceptual understanding as the "high kids"(*The Myth of Low Kids and High Kids*, 2019). Labels and language impact instruction and student's identities (Aguirre et al., 2013; Boaler, 2016; Martin, 2000; National Council of Teachers of Mathematics, 2023; Smith et al., 2021). To challenge the "high kids/low kids" deficit culture of ableism and create a culture that values what students bring to the classroom it is necessary to focus on what students can and do understand (Boaler, 2016; Delaney & Mayer, 2021; Keown & Bourke, 2019; *The Myth of Low Kids and High Kids*, 2019). Often, teachers ask students to take on a growth mindset in the classroom, however, not all teachers embrace the growth mindset they ask their students to practice (Aguirre, 2022) which influences the learning environment. The classroom environment can strengthen a student's math identity or challenge and even diminish the idea that they belong in mathematics (Aguirre et al., 2013; Boaler, 2016; Gonzalez, 2023; Martin, 2000). "Hierarchical and exclusionary ways of understanding mathematics and mathematical ability are deeply ingrained in the cultural assumptions and systems that dominate our society. Rejecting ability labels is a necessary part of dismantling these harmful assumptions and systems" (National Council of Teachers of Mathematics, 2023, paragraph 7). Therefore, teachers need to reflect and see if instruction and teacher language are providing opportunities for all learners reflective of a strength-based, growth mindset grounded in research based practices. Intentionally or not, educators' and school systems' values, norms, and biases will shape the learning environment (Aguirre et al., 2013; Cioè-Peña, 2021; Leyva et al., 2021; Martin, 2000). The learning environment and learning opportunities students have played a part in determining what possibilities are available to them in the future.

Additionally, cultural values and how math is perceived in society don't always match what quality instruction should look like for all learners. It is socially acceptable to brag, "I'm not a math person" or to not be "good" at math, as negative attitudes are prevalent in society and media around math understanding and are sometimes fostered by math anxiety (Boaler, 2016; Gonzalez, 2023). Math anxiety is a real issue, and traumatic experiences can build from school experiences. I am reminded of this when hearing students talk about not belonging, being stressed, being yelled at for counting their fingers, or feeling rushed in math class. This reminds me that conversations need to continue to establish what we expect math learning to look like. Tears from middle school students or painful memories from adults when retelling their math experiences, noting when they started to feel bad in math at times being able to name the specific grade level when it happened, reinforce the ongoing impact of these experiences and emotions. Engaging in these conversations with students is an actionable step, an action that puts energy into solidarity with students, rather than trying to do everything, and focusing on how the system works and aligning solidarity with students rather than the system, as suggested by Dr. Annamma (Annamma & Winn, 2019).

My experiences with learners reinforced that the needs of the students are central, and the need to be in solidarity with them, especially when inequity exists. To advocate for students, and keep their needs at the forefront when in meetings with colleagues, I might raise questions such as “How is this accessible for all students? What can be done to support all learners? I think they should be in the classroom for grade level instruction, when can we meet and plan what that looks like so they can engage?” These conversations and topics of access and equity drive my research interest. These experiences shape my professional identity, they are part of my identity that I bring into my research along with my other experiences, personal identities, and learner identity. As a researcher, I recognize that I bring myself into the evolution of my researcher identity that will continue to be shaped as I conduct my research.

Definition of Terms

Common Core State Standards (CCSS): There is not a single set of national standards in mathematics all but nine states and one territory have not yet adopted the CCSS, therefore, when referring to standards and expectations CCSS are the ones used (Common Core State Standards, 2010).

Deep Learning: Constructing knowledge through experiences, collaboration, and conversation, to make meaning conceptually and build connections between ideas. This term will be used as there are a variety of terms – experiential learning, critical explorations, inquiry-based learning, developmental education, and progressive education used in the research.

Discourses – “Discourses include institutions, actions, words, and taken-for-granted ways of interacting and operating. So, in some ways, discourses can be thought of more like paradigms in which we operate. Discourses reflect a particular point in history, including specific relationships between people, knowledge, and agency; they come to define what we think of as 'normal' " (Gutiérrez, 2013, p. 43) like norms and logics (Leyva).

Equitable math instruction: Access to conceptual understanding, application/problem solving, procedural fluency, and the Mathematical Standards of Practice as outlined in Common Core State Standards (CCSS) and the National Council of Teachers of Mathematics (NCTM) position statement: "Practices that support access and equity require comprehensive understanding. These practices include, but are not limited to, holding high expectations, ensuring access to high-quality mathematics curriculum and instruction, allowing adequate time for students to learn, placing appropriate emphasis on differentiated processes that broaden students' productive engagement with mathematics, and making strategic use of human and material resources. When access and equity have been successfully addressed, student outcomes—including achievement on a range of mathematics assessments, disposition toward mathematics, and persistence in the mathematics pipeline—transcend, and cannot be predicted by students' racial, ethnic, linguistic, gender, and socioeconomic backgrounds" (National Council of Teachers of Mathematics, 2014a, p. 1)

Intersectionality: The essence of who you are, your many traits and characteristics, intersections of aspects or components of one's identity, and systems of oppression exist, with marginalized and multiply marginalized people facing interlocking oppressions (Annamma & Winn, 2019a; Crenshaw, 2016).

Learning Differences (LD): students with disabilities or learning differences, either with or without a diagnosis, and who may or may not be receiving support based on these diagnoses or labels.

Mathematical Identity: How a person views themselves as a math thinker, what they see as possible for themselves in the future, and in learning math, as defined in the research on mathematical identity. "…[T]he dispositions and deeply held beliefs that students develop about their ability to participate and perform effectively in mathematical contexts and to use mathematics in powerful ways across the contexts of their lives" (Aguirre et al., 2013, p. 14). "… beliefs about (a) their ability to perform in mathematical contexts, (b) the instrumental importance of mathematical knowledge, (c) constraints and opportunities in mathematical contexts, and (d) the resulting motivations and strategies used to obtain mathematics knowledge" (Martin, 2000, p. 19).

Teacher identity: Who someone is as a teacher, what you believe makes you a teacher, and what you hope to be when you envision yourself as a teacher.

Background

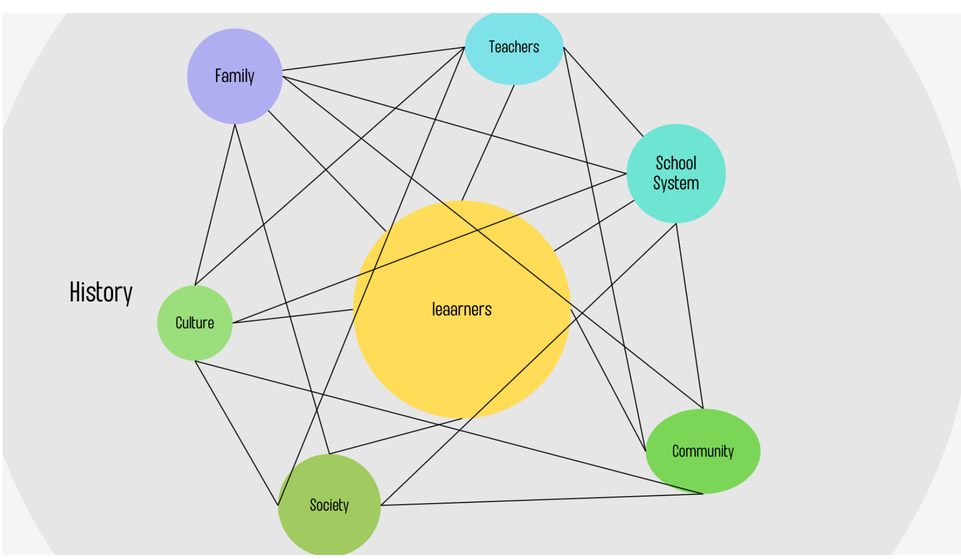
In the United States, there is a widespread fixed mindset about mathematics, reinforcing the false belief that there are "math people" and "non-math people" (Boaler, 2016; Dweck, 2006; Gonzalez, 2023; Keown & Bourke, 2019). In reality, neuroplasticity means that brains are capable of growing connections and learning new things. Therefore, anyone who is given time and opportunity can learn mathematics (Boaler, 2016; Dweck, 2006; Keown & Bourke, 2019). The belief that math ability can change allows students to envision their learning potential and can help them to more easily embrace a positive math identity. Messaging comes from the community and through representations of mathematics in media and entertainment (Gonzalez, 2023). Several factors influence the development of mathematical knowledge, beliefs, mindset, and mathematical identity. These factors include society, family, life experiences, knowledge, culture, and intersections of one's identity (Aguirre et al., 2013; Boaler, 2016; Gonzalez, 2023; Martin, 2000, 2019; Parks, 2020; Tatum, 2017).

Learners receive messages about mathematics in all areas of their lives creating urgency in Martin's (2000) call to recognize not only how these messages shape interpersonal experiences and interactions within schools and communities, but to also frame these experiences and interactions within the sociocultural context, as shown in Figure 1.

Figure 1

Influences on Mathematical Identity

This image illustrates the overlap and connections around how learners are situated based on factors outlined by Martin (2000) in defining Mathematics Identity. The learner is at the center existing within historical contexts, their culture, society, and community, and is influenced by school systems, family and teachers which all exist within the influences of culture, society, community, and history. The connections are bidirectional all set within the context of the past and shaping current history.



Educational systems, teacher practices and instruction, and access to experiences also contribute to the development of beliefs, construction of knowledge, and shaping of identities. For example, policies that facilitate the development and implementation of standards can impact how teaching and learning are structured. It is this bidirectional influence, in Figure 1, that demonstrates the complexity and impact that interactions and experiences have on one another. Teacher practices and instructional routines can shape learners' experiences that impact the development of their identities, mindsets, and math content knowledge. While recognizing and acknowledging the outside forces at play, this study focused on the influence and impact of school experiences, shown as the school systems, teachers, and learners' connections in Figure 1, and how they can limit or support equitable access to positive mathematical identities and equitable mathematics instruction for learners.

Statement of the Problem

Mathematics instruction is not equitable for all students (Aguirre et al., 2013; Boaler, 2016; Gonzalez, 2023; Martin, 2000). "There must be acknowledgment of the unjust system of mathematics education, its legacy in segregation and other forms of institutional systems of oppression, and the hard work needed to change it" (National Council of Supervisors of Mathematics & TODOS: Mathematics for ALL, 2016, paragraph 3). Access to equitable math instruction includes the opportunity to be a participant in the learning space, the chance to explore and engage with rich tasks to build conceptual understanding, and access to an identity to see oneself as a person who can do mathematics (Aguirre et al., 2013; Boaler, 2016; Huinker, 2020; Martin, 2000; National Council of Teachers of Mathematics, 2018). When looking at international mathematics testing data, not only does the United States fall short on problem-solving and application compared to other countries, but the inequities between marginalized groups are evident in the assessment data (Huinker, 2020; National Council of Teachers of Mathematics, 2018). Systemic structures exist that limit access for some populations (Boaler, 2016; Martin, 2019). Ableism, classism, and racism all influence experiences and the normalization of particular ideals and norms that are based on Whiteness and impact systems and structures (Annamma & Winn, 2019; Leyva et al., 2021). Meaningful and significant systemic change is even harder when the system is designed to self-correct to maintain the status quo (Aguirre, 2022; Gonzalez, 2023; Martin, 2019; Stewart, 2017). Changing instruction is difficult and requires conscious effort, recognizing that without reflection, we "will continue to perpetuate inequity across racial and socioeconomic lines, whether it be consciously or unconsciously" (Seda & Brown, 2021, p. 17).

To make shifts, considering the history and background of disciplines as well as systems of education will be necessary. "Colorblind, genderneutral approaches to instruction are rooted in logics of mathematics as a neutral, value-free discipline and mathematical ability as innate, which obstruct instructors' perceptions of how systemic forces create seemingly neutral practices that are oppressive to historically marginalized students." (Leyva et al., 2021, p. 788). As Kendall (2013) notes while historical events were not started or necessarily even supported by white people in the present time, there are systems and structures in place that people fail to recognize, ignore, or don't challenge that are reinforcing systemic racism, white superiority, classism, and patriarchy. Ableism is found in practices and policies in systems of special education (Loutzenheiser & Erevelles, 2019). The normalization of English, along with ableism, leads to inequities of multilingual learners regarding under or overqualification for special education (Lei et al., 2020). These norms also place limits on access to needed accommodations and services that are provided exclusively in English creating an additional divide between home and school (Cioè-Peña, 2021). To create more equitable instruction, reflection on learner's experiences and their teaching is important for educators to do (Darling-Hammond & Oakes, 2019; Duckworth, 1987; Loughran, 2006; Miller & Shifflet, 2016).

Mindset not only plays a role in how we make decisions but also in how we react or reflect on our experiences (Dweck, 2006). Teachers' identities, beliefs, and biases shape pedagogy and, thereby the classroom environment, either intentionally or unintentionally, which defines access for students (Armstrong, 2010; Boaler, 2016). When considering access to the identity of a mathematician and access to mathematics classes, the systems of education that reinforce this inequity are clear. Allison and Pomeroy (2000) "…suggest asking questions such as, 'What processes are at work in this situation?' or 'What are participants perspectives on the experiential education program?' " (p. 96). Reflection on the part of educators is a powerful practice that can also support consideration of teaching practices different than those that an educator may have experienced themselves, what Loughran (2006) refers to as "apprenticeship of observation" (Darling-Hammond & Oakes, 2019; Loughran, 2006; Miller & Shifflet, 2016). Self-reflection is one aspect of making shifts in practice, thereby making shifts in instructional environments.

Considering learners' attitudes and experiences and reflecting on how society and culture position mathematics is essential for math education focused on social justice and equity (Aguirre et al., 2013; Gonzalez, 2023; Martin, 2000). Many studies focus on math anxiety and while those are expanding to younger students much of that work has been done with older students in the past (Dowker et al., 2019). Studies have shown a decrease in positive math attitudes reported over time, and an increase in math anxiety which impacts and is impacted by performance (Dowker et al., 2019). Some studies have also noted that attitudes predicting performance are more related in grade three than in younger grades (Ganley & McGraw, 2016). In adding stories and counternarratives to examine the diverse experiences and stories that exist, research can support transformations and critical reflection on power and inequities in the educational system.

Purpose of the Study

The purpose of this study is to better understand the perspectives elementary learners have of their experience in math class. Developing instruction with goals of equity and access without asking the learners themselves about their experience leaves out essential student perspectives (Allison & Pomeroy, 2000; Lambert et al., 2020; Parks, 2020). Mathematical identity is an essential aspect to consider concerning creating equitable math instruction (Chronaki, 2017; Martin, 2000). A majority of educational research focuses on curriculum, with little focus on mathematical identity, part of this research shift includes looking at discourse and social interactions rather than exclusively school structures (Gutiérrez, 2013) "By knowing the mathematical identity of students, researchers expect to get a better understanding of the relationships that are built between students and mathematics" (Hima et al., 2019, p. 461).

There are limited studies that elicit perspectives from students with disabilities or labels (Daley & Weisner, 2003) or studies that add young learners' voices (Leyva et al., 2021), specifically in mathematics. Parks (2020) recognizes that students who are on the margins and those who think or engage in diverse ways might not have their thinking and participation recognized when it looks different. Researchers acknowledge ". . . more research needs to represent mathematics lessons from the perspectives of children and youth, particularly those students who engage with teachers infrequently or in atypical ways" (Parks, 2020, p. 1443). Documenting student perspectives of math class from kindergarten to grade five will contribute to adding stories and narratives to the research and educational conversation about the development of more equitable instruction (Annamma & Winn, 2019; Delaney & Mayer, 2021; Guzmán, 2019) that is limited in educational research (Parks, 2020).

Arts based research provides a way for learners to express themselves and gain their perspective on experiences through art rather than verbal expression alone (Gamradt & Staples, 2023; Haney et al., 2004; Parks, 2020; Søndergaard & Reventlow, 2019; Stiles et al., 2008). Researchers have found using a larger collection of student drawings allowed them to develop a richer understanding and insight from their perspectives adding to limited data on learners' experiences (Haney et al., 2004), to "provide greater understanding of the topic" (Leavy, 2017, p. 168). As connections are made between data points, a more comprehensive understanding of students' experiences and emotions during their younger years as they are forming their math identity, linking the structures of social interactions and identifying patterns within these structures (Zhao et al., 2021).

Guiding Research Questions

- What are different ways students perceive and express their experiences in math class?
- What are the similarities and differences in math class experiences in early elementary (K-2) in comparison with upper elementary (3-5) as portrayed by the learners?
- What are some of the visible elements of math class are portrayed by learners that align with or differ from the elements of mathematics named by teachers?

Design of Study

This mixed methods research examined district data to consider elementary students' portrayal of math class. The integration of arts-based methods (Haney et al., 2004), qualitative and quantitative data analysis, along with a critical lens (Gutiérrez, 2013) was used to consider the learner's experiences. Identity theory (Farnsworth et al., 2016; Hogg et al., 1995; Martin, 2000) and a constructivist lens value perceptions and experiences as critical components of building a mathematical identity and are key for deep learning (Allison & Pomeroy, 2000; Delaney & Mayer, 2021; Ladson-Billings, 2017; Mehta & Fine, 2019). Through each learner's reflections on what learning math looks like and studying how they feel about themselves as math learners, insight is gained into the lived experience of students (Zhao et al., 2022).

The drawings were coded, this quantizing transformed the codes into quantitative data that allowed for exploration of the presence or absence of characteristics in the drawings (Leavy, 2017). Codes from "Drawing on Math" were used because this aligned with the math drawing survey used by the district. Quantitative data allowed for the exploration of similarities and differences in drawings of younger elementary students (grades K-2) and older elementary students (grades 3-5). Given that research shows a difference in math attitudes tending to be around 3rd grade (Ganley & McGraw, 2016), this comparison explored if there are differences represented in student attributes. Types of math and elements in the classroom were also compared to the defining features of mathematics that teachers identified and to the elements for classroom environments that support deep learning.

The qualitative data analysis was conducted from a subset of drawings used in the quantitative analysis. Exploration of a small set of drawings allowed more of the stories depicted to be represented. Memos about the drawings provided details about how the learners represented math class including any words or captions they wrote. While the quantitative analysis provided information about a big group and general information, the qualitative data provided individual narratives with more details about the drawing of a learner's experience.

Expected Contributions to the Field

This study explored the phenomenology of learning mathematics in the elementary classroom. Identity development, including emotions and attitudes around mathematics, is a critical consideration, as the impact of engaging in mathematics and seeing oneself as capable of mathematics and belonging in mathematics has implications for academic opportunities and careers (Aguirre et al., 2013; Boaler, 2016; Chronaki, 2017; Leyva et al., 2021; Stiles et al., 2008). This study documents how younger children feel about mathematics education and their experiences in learning math. As Leyva (2021) suggests sharing this data can add to conversations about PK-12 math classrooms that can lead to changes in mathematical learning spaces and opportunities for students. This builds on existing work being done to disrupt and uncover the logics, structures, and cultural norms in the educational system around who is and is not a mathematician (Chronaki, 2017; Leyva et al., 2021). "[A] focus on identity and power is appropriate for understanding and improving the conditions not just for marginalized students, but for all students" (Gutiérrez, 2013, p. 49).

Developing instruction with goals of equity and access, and then not asking the students themselves how the experience is working is leaving out an essential user from the conversation. This research adds this essential voice to the conversation. Exploring how students represent math learning and themselves as learners is a foundation that contributes to this discourse around access to positive math identities and equitable math instruction. Examining learners' perceptions of, beliefs about, and response to math class provided a glimpse into their experiences and emotions in math class. Using data that includes students' portrayal of math class, has added awareness for the district about their students by incorporating student perspectives as they refine and revise their math vision, by using a tool that has been found to impact instruction when drawings were reviewed and reflected on by educators (Haney et al., 2004). Reflection is known to be effective for teachers to learn, integrate ideas, and consider shifts to pedagogy and practice (Darling-Hammond & Oakes, 2019; Dewey, 2001; Hawkins, 2002; Loughran, 2006). This information is useful not only for teachers and districts as they consider what math class looks like but also in education overall. Greater awareness of students experiences can enhance the planning of courses for educators and preservice teachers, professional development, and/or designing equitable instruction (Gutiérrez et al., 2023). This knowledge is more powerful and accurate than observations alone and learner's perceptions of their experiences are more accurate as they can speak best to their own experience.

CHAPTER TWO: Review of Literature

Although mathematics instruction and curriculum are typically perceived as neutral, research has shown they are not neutral (Leyva et al., 2021). Ableism, classism, and racism, which are all rooted in the normalization of perceived ability and Whiteness, also impact learners' experiences and uphold systems and structures that privilege some learners and marginalize others (Annamma & Winn, 2019a; Battey & Leyva, 2016; Leyva et al., 2021). These systemic structures act as gatekeepers limiting access to mathematics for some populations (Boaler, 2016; Martin, 2000, 2019). Historically marginalized students are oppressed by these systems (Leyva et al., 2021) which often go unchallenged (Kendall, 2013). Practices and policies within systems of special education have been found to support ableism (Loutzenheiser & Erevelles, 2019). The intersectionality between the normalization of English and ableism leads to inequities for many multilingual learners resulting in disproportionate representation in special education (Lei et al., 2020) as well as limited access to accommodations and services to English (Cioè-Peña, 2021). Furthermore, research on students with learning differences has primarily relied upon quantitative methods undergirded by deficit orientations examining a narrow scope of math that does not encompass the complex nature of numbers and mathematics (Bowman et al., 2019; Lambert & Sugita, 2016; Lambert & Tan, 2020; Tan et al., 2019; Woodward & Tzur, 2017). "Special education, thus, reproduces the ableist ideologies, practices, and policies of education that justify the segregation of these students from the everyday routines of educational life" (Loutzenheiser & Erevelles, 2019, pp. 376–377). The deficit orientation often leads to different expectations for students and reduced rigor and opportunity for them in mathematics (DeJarnette et al., 2020; Xin et al., 2016). "In educational contexts, the association of race with disability has resulted in large numbers of students of color (particularly African American and

Latino males) being subjected to segregation in so-called special-education classrooms through sorting practices such as tracking and/or through labels….” (Erevelles & Minear, 2010, p. 113).

Perceptions of students based on their race, class, or other aspects of their identities along with labels can result in inaccurately prejudging their ability, lowering expectations, and limiting their access to conceptual understanding and development of problem-solving skills needed to understand the world and to have options for future careers. (Aguirre, 2022; Aguirre et al., 2013; Boaler, 2016; Chronaki, 2017; Gonzalez, 2023; Martin, 2000; Smith et al., 2021). Low income students, students with disabilities, and students of color have had fewer opportunities to engage with the math which is expected from mathematics reforms including problem-solving and challenging curriculum (Kitchen et al., 2016; Lambert & Sugita, 2016). High-stakes testing creates, reinforces, and normalizes the use of labels, blaming students, and lowering academic expectations for some groups of students (Garcia-Olp et al., 2017; Kitchen et al., 2016). Testing is not in line with these math reform expectations and instead focuses on low-level skills, reinforcing the focus on low-level skills in the classroom (Kitchen et al., 2016).

> This practice of attaching a label to students based upon their performance on the high-stakes test constructed some students as less capable than others in mathematics. Such practices contribute to the historic legacy in the U.S. of denying poor students and students of color access to a challenging education in mathematics (Kitchen et al., 2016, p. 17)

Inequitable deficit orientation blocks learners from receiving the deep conceptual foundation that is needed for learners with mathematical difficulties to become flexible mathematicians (Gibbs et al., 2018; van Garderen et al., 2020; Yeh et al., 2020). One example of this limited access comes from findings that suggest computational fluency is often identified as the goal or primary need for students with learning disabilities (LD) (Lambert & Sugita, 2016). However, this does not have to be mastered to work on problem-solving and reasoning tasks (Lambert & Sugita, 2016, Xin et al., 2020). Students with LD should engage in problem-solving tasks and not wait or only focus on computation (Xin et al., 2016). These instructional practices seem to be derived from conflicting methodologies, contributing to a siloed approach in both mathematics education research and mathematics instruction which is furthering inequitable experiences for learners.

Constructivist Shifts in Research

Due to current mathematics standards, the increase in expectations of all students demands a change in education and instruction, and research can provide further insight into those changes. All learners, based on current standards, are expected to engage with practice standards and have a deep conceptual understanding of mathematics (Common Core State Standards, 2010), which does not match up with prior expectations (Bowman et al., 2019). Although not prevalent, some special education researchers are moving to a more constructivist lens for students with LD. By using a neurodiverse view or nature of disabilities lens, where one recognizes the biological and inherent neurodiversity of individuals, students are seen as being differently abled and not disabled (Armstrong, 2010; Tan et al., 2019). Acknowledging differences as strengths rather than deficits allows for different research approaches. For instance, social justice and equity in math instruction have been examined more recently through a socio-political perspective (Boylan, 2016).

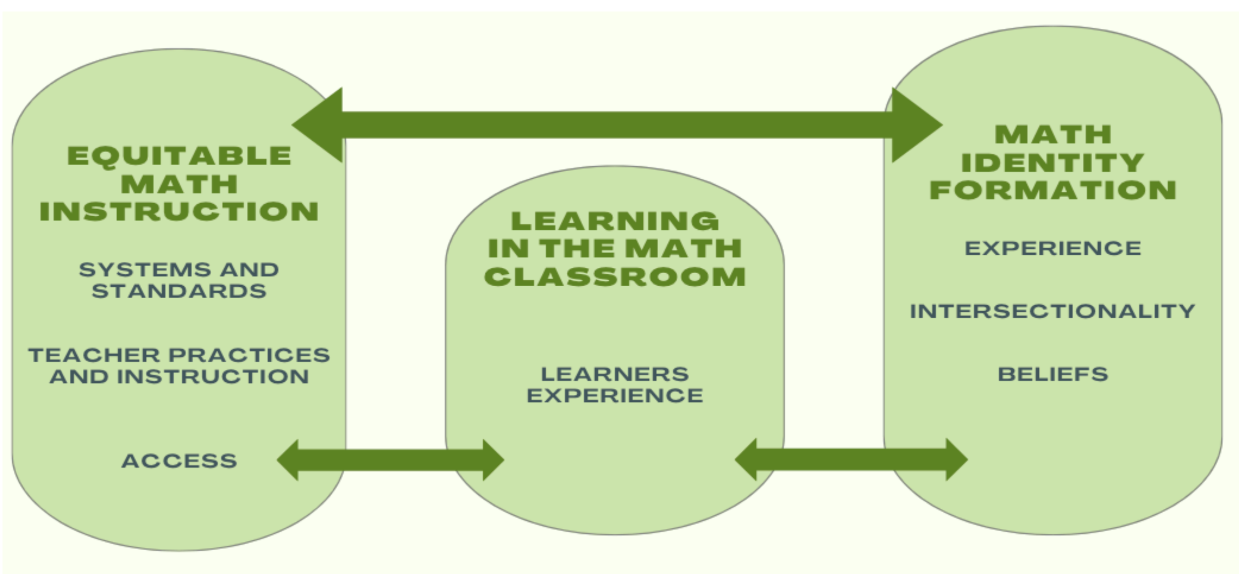
Furthermore, by integrating research methods and instructional practices from different educational fields, for example special education and math education, student learning can be enhanced (van Garderen et al., 2020). One longitudinal study integrated special education and mathematics research to provide interventions. The study demonstrated growth in conceptual development and increased targeted justification use by students over the course of the interventions (van Garderen et al., 2020). Other research provides additional examples of how research across academic domains using more strengths-based or constructivist approaches can positively impact learning for all students. Xin and colleagues (2016) outline a unique case study that examined constructivist small group teaching for a student with an LD. This qualitative study extended beyond the limits of quantitative analysis, rather than data on correct or incorrect answers the analysis focused on the tasks, discourse, and questioning used during instruction to consider their impact on building conceptual understanding (Xin et al., 2016). Looking at data in this way can uncover relationships between these instructional strategies and student understanding of mathematical models which can determine the next instructional steps. Qualitative methods were also used by Woodward & Tzur (2017) when examining four studies that use a constructive learning pedagogy, relying on responsive teaching methods, that were challenging the common ideas about curriculum, scripted lessons, and interventions in special education (Woodward & Tzur, 2017). This is an example of research on students with LD, with a constructivist lens and alternative ways to look at and implement a curriculum that moves beyond basic skills and was a shift from past research on math LD to incorporate some of the research aspects from math education research (Woodward & Tzur, 2017). It also provides an example of the value of pedagogical content knowledge, the knowledge held by educators, which is not common in research for “at risk students” (Woodward & Tzur, 2017). Responsive teaching allows students to receive timely feedback and instruction to meet their immediate instructional needs (Darling-Hammond & Oakes, 2019; Hawkins, 2002; Kolb, 2015; Roosevelt & Garrison, 2018).

Increased focus on instruction for students with disability or difficulty in math, can showcase instructional strategies that benefit all learners (Lambert & Sugita, 2016). Inclusion of all students in the classroom learning community, where all learners are active valued participants contributing thoughts and ideas, requires that everyone have equal access to deep rich math opportunities. Shifting research and educator collaboration can foster this learning environment (Bagger et al., 2020). This collaboration can impact learners' experience in the classroom through influence on math identity formation and equitable math instruction. The relationship connections and influence of these elements are depicted in Figure 2 and are detailed in the review of literature that follows.

Figure 2

Influences on Learning Math in the Math Classroom

This figure shows the interconnected relationships between math identity formation, learning in the math classroom, and equitable math instruction.



Identity Formation

In considering children's development of their mathematical identities, it is necessary to acknowledge the intersectional aspects of their identity as well as the influence of history, experiences, community, and society on the development of identity (Hima et al., 2019; Martin, 2000; Yeh et al., 2020). Identity is not static, it is continuously evolving and changing (Gresalfi & Cobb, 2011; Hima et al., 2019; Tatum, 2017) based on experiences and interactions as people grow and develop (Farnsworth et al., 2016). Identities are complex encompassing the intersectionality of individuals, aspects of their life, background, experiences, and community (Aguirre et al., 2013; Crenshaw, 2016; Martin, 2000; Tatum, 2017). Power dynamics, social norms, and/or perceived roles affect what aspects of one's identity are exposed, and which aspects remain hidden in different places and around different people (Gresalfi & Cobb, 2011; Martin, 2000; Paris & Alim, 2017). Deciding what version of oneself is shared is determined in part by expectations from others or in attempt to "fit in" within different environments. Relationships, labels assigned by others, and beliefs held by themself and others influence individual identity development (Annamma & Winn, 2019). This is a component of social learning theory, as defined by Wenger-Trayner, which recognizes that "a central drive for the negotiation of meaning is the process of becoming a certain person in a social context – or more usually a multiplicity of social contexts" (Farnsworth et al., 2016, p. 7). As learning is occurring, so is identity development through relationships and interactions with people and the world (Aguirre et al., 2013; Farnsworth et al., 2016; Martin, 2000).

Mathematical identity shapes children's beliefs about themselves as learners and doers of math, as well as their value in learning mathematics itself as they consider what futures they see possible for themselves (Chronaki, 2017; Cobb et al., 2009; Gonzalez, 2023; Martin, 2000).

Although mathematical identity and an individual's relationship with mathematics continue to evolve the primary focus of this literature review is on children's mathematical identity development during their school years.

Influences on Math Identity

Mathematical identity is formed with multiple layers interacting and intertwining to influence the development of identity, including teachers, students, community, and society (Gonzalez, 2023; Martin, 2000). Identity is shaped by race, gender, socioeconomic status, dis/ability, environment, experiences, culture, values, and mindset (Boaler, 2016; Cobb et al., 2009; Hima et al., 2019; Martin, 2000; Tatum, 2017). To make improvements to math education and access, it is necessary to recognize, understand, and examine how the educational system exists within a society built on inequities that disproportionately impact particular groups. This system results in privilege for some and marginalization for others (Gonzalez, 2023) as defined by norms and logics embedded in policies, practices, and customs within society that are reinforced in schools (Gresalfi & Cobb, 2011). Power, privilege, and inequity within society must also be examined when considering access and marginalization (Gonzalez, 2023). Nothing happens in isolation, and the experiences students have both in and out of school are all influencing identity formation. Due to the complexity and ongoing evolution of identity, multiple aspects and influences that shape identity simultaneously influence cannot be attributed to a single factor or social setting.

Community and Culture

Knowingly, or unknowingly, people may adopt societal norms and ideas anchored in bias and prejudice. These inaccurate perceptions and beliefs about people and what roles are possible for people, at times based on race, class, gender, ability, or other intersectional aspects of identity can inappropriately drive what expectations and possibilities are available to students when considering their future (Delaney & Mayer, 2021; Martin, 2000; Tatum, 2017). Within society, there are ideas and perceptions around the purpose and use of mathematics. Gender, socioeconomics, race, and ability are just some intersecting aspects of identity (Aguirre et al., 2013; Crenshaw, 2016) that may be a source of stereotypes. Societal prejudices influence math socialization and interactions within a community which adversely influence individual's attitudes around learning, beliefs about the purpose of math, perceptions of mathematicians and mathematics, and math stereotypes (Gonzalez, 2023).

Family

Generational and historical attitudes towards learning, education, and possibilities for future choices are also shaped by the values that are held within families. Parents or caregivers who have faced trauma, anxiety, or discrimination when learning mathematics might hold and share negative attitudes, thoughts, and experiences (Buckley et al., 2016; Tomasetto et al., 2021). This might include comments like "I was never good at math either" or "I don't have a math brain" thereby maintaining the notion it is socially acceptable to identify and believe that one is "bad at math" (Gonzalez, 2023). Furthermore, attitudes about mathematics and what opportunities are available or limited can be influenced in part by tracking or exclusion faced by parents. Research documents instances where discrimination left individuals out of learning or denied them access to mathematics which, in turn, shaped their views about school and math. Martin (2000) found when interviewing African American parents that their own experiences shape how they interact with their children and mathematics, as well as the expectations they have for their children at school and their children's future. In one case, a mother who experienced a lack of caring and belief in her ability to do mathematics in school had low expectations for her children, as an adult lacked the confidence and knowledge to help her children, and demonstrated inconsistency in the value she placed on math education. Another mother had completed only the basic required math classes, despite this negative experience as a child, her attitude and confidence changed when taking math as an adult for her job. Over time she recognized the value of mathematics, and its impact on socioeconomics, and expected her children to learn and was critical of the experience and lack of encouragement her children were receiving (Martin, 2000). Experiences and social norms have influenced values that can get passed on.

Schools: Systems, Values & Labels

Schools are microcosms of society. Education culture and values are founded on white monolingual norms (del Carmen Salazar, 2013; Paris & Alim, 2017). Therefore, racism, sexism, ableism, classism, and other biases and prejudices exist within beliefs around mathematics, and notions of who is capable of mathematics show up in schools (Gonzalez, 2023; Gutiérrez, 2013; Leyva et al., 2021). Math is human, political, social, and cultural and there are power dynamics at play in education (Gutiérrez, 2013). When studying access to mathematics classes, math content, and mathematical identity in education the systems that reinforce this inequity are clear.

According to Rosemary Mkhize, schools are “identity-forming agents” (Hima et al., 2019, p. 463). Learners' identities are, in part, shaped by their experiences, expectations, and values imparted by teachers and other adults in their lives (Aguirre et al., 2013; Hima et al., 2019; Martin, 2019). These identities can be shaped, reinforced, or challenged by the educational systems in place. For some students school experiences remove their culture and heritage when there are expectations of assimilation for students of color or immigrants (del Carmen Salazar, 2013). Too often in schools, culture is viewed as a deficit and for students of color with learning difficulties dehumanizing pedagogy results in their learning difficulties being attributed to home situations and culture (del Carmen Salazar, 2013). Historically schools have segregated marginalized students based on identification through special education (Annamma & Winn, 2019). For example, English IQ tests created language barriers resulting in multilingual students being identified for special education in the 1970s (Annamma & Winn, 2019). Unfortunately, identifying students with difficulties or disabilities is not always equitable for all learners even today. For instance, English Learners (EL) may be identified as LD because of a lack of resources and support, resulting in overqualification; conversely, some ELs are under-referred because of delays in mastering English as well as varying definitions of EL with LD (Lei et al., 2020). Traditionally, the majority of research in special education has been based on the medical model, related to skills and acquisition of procedures to get to answers rather than targeting productive struggle, conceptual understanding, strengthening connections (van Garderen et al., 2020), and engaging with the full complexity of number sense and mathematics (Lambert & Tan, 2020; Tan et al., 2019). These examples demonstrate how systems, beliefs, and labels both reinforce and influence who has access to what type of instruction.

Reinforcement of oppression has also impacted who has or hasn't been welcomed, safe, and represented in schools and curriculum illuminating the historical and ongoing impact on identities (Annamma & Winn, 2019; Paris & Alim, 2017). The use of mathematics as a gatekeeper contributes to systems of testing and elevates mathematics with great power while reinforcing deficit focus (Gutiérrez, 2013). Studies show that students of color are denied placement in certain classes, like algebra, based in part on teacher recommendation, lack of homework completion, or perceived potential difficulties, despite having the grades, prior course requirements, and data demonstrating they should be in the course. (Boaler, 2016; Martin, 2019). This is discriminating against minority students based on factors that impact them disproportionately (Boaler, 2016) and exemplifies how perceptions of students based on their labels, identity, or background influence systems and decision-making processes that deny access and opportunities to some learners (Aguirre et al., 2013).

Labels (i.e. high group, low kids, ELL, IEP kid, tier 3 kid) may become defining for students, and marginalized groups tend to end up with multiple labels. This can be harmful, leading to segregation as well as messaging around beliefs in students, potentially placing identities on students (Annamma & Winn, 2019) or resulting in students holding negative stereotype identities. In education, like in society, there is most often a deficit focus, defining students by what they cannot do, where differences are seen as deficits (Tan et al., 2019), and learners as the problem (Garcia-Olp et al., 2017; Paris & Alim, 2017). Students are seen as lacking, needing to be fixed, rather than focusing the conversation on the learning environment (Tan et al., 2019) and building upon students existing knowledge and strengths, through flexible asset focused pedagogies (Paris & Alim, 2017) and this can limit the value given to other ways of thinking about mathematics or approaching a task.

Labels (such as “high”, “low”, and “IEP”) can become expectations; they can limit how students are seen, how their abilities are perceived, and how their learning may be limited (Paris & Alim, 2017; *The Myth of Low Kids and High Kids*, 2019; Yeh et al., 2020). This can have negative implications for all students. Testing proficiency categories can result in labels that suggest who can or cannot, grow to “proficient” mathematicians (Kitchen et al., 2016). Learners being labeled “high” or “gifted” may lead to the perception their ability is innate and perceive personal failure when they encounter tasks that take perseverance and productive struggle so they resist risks (Boaler, 2016). Labeling students as “low” is problematic, as they feel unable to succeed and put undue pressure on themselves, or lack confidence in their ability to learn, impacting their learning and experiences (Boaler, 2016; Smith et al., 2021; *The Myth of Low Kids and High Kids*, 2019) , and can therefore meet only those "low" expectations placed on them. Furthermore, as labels of math abilities are aligned to the perceived racial hierarchy of mathematics, this results in tracking and different expectations for tasks and cognitive demands for students based on race.

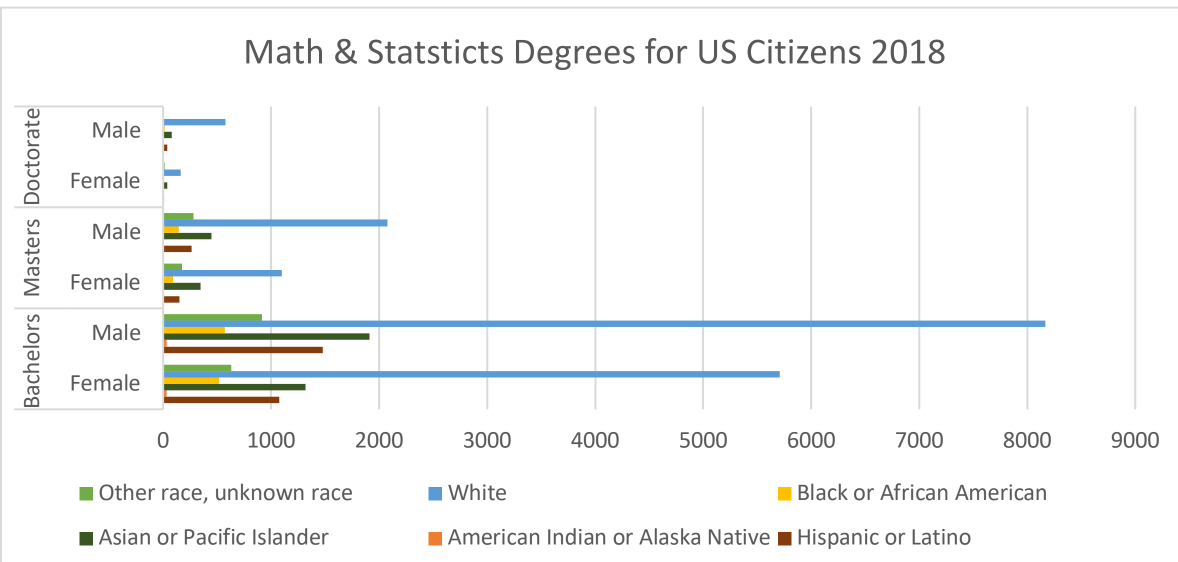
While labels in educational systems can influence the formation of identity, identity may be impacting access to math instruction. Mathematics manifests as a gatekeeper and part of systemic racism in education, denying and limiting Black and Latinx students' access to mathematics, as reflected in several studies (Boaler, 2016; Gonzalez, 2023; Martin, 2019). The predominance of white male students obtaining degrees in mathematics and statistics, as seen in Figure 3, highlights these differences (Boaler, 2016; National Science Foundation, 2018). Boaler (2016) suggests that "to achieve higher and equitable outcomes we need to recognize the elitist role that mathematics often plays in our society" (p. 93). Conversations among educators are needed that contribute to a larger exploration of privilege, oppression, and social justice in education (Guzmán, 2019). These conversations must be done in a way to avoid "gap gazing" or centering whiteness by using that as the measure of comparison and instead look at identity and power (Gutiérrez, 2013). Considering bias, mindset, and language, is of importance and can provide another shift:

> In fact, the greatest change that can be made is one that costs little or nothing: changing the attitude of educators toward kids with labels. The only way inclusion will really work is by convincing teachers that those students who have been traditionally excluded from the 'regular classroom' are going to be a positive addition to their classroom. (Armstrong, 2010, p 201)

Figure 3

Math and Statistics Degrees by Race and Gender

National Science Foundation Data from 2018 US Degree Recipients demonstrates the number of degrees at the Bachelor, Masters, and Doctorate level by gender and racial groups. This graph specifically shows the number of degrees in mathematics and statistics for US citizens in 2018. The data for Doctorate Degrees of American Indian or Native Alaskan and Other Race, the unknown race category is suppressed for males. Native Hawaiian or Pacific Islander male data is also suppressed and is not included in the Asian or Pacific Islander Doctoral Degree data for Doctorate Degree (National Science Foundation, 2018)



Note: Data for Doctorate Degrees of American Indian or Native Alaskan and Other Race, the unknown race category is suppressed for males. Native Hawaiian or Pacific Islander male data is also suppressed and is not included in the Asian or Pacific Islander Doctoral Degree data for Doctorate Degrees.

Growing research in mathematics education has led to shifts in instructional strategies along with calls to focus on equity in math class expecting that all students will have opportunities to build conceptual understanding, skills, and habits of mathematicians (Common Core State Standards, 2010; National Council of Supervisors of Mathematics & TODOS:

Mathematics for ALL, 2016; National Council of Teachers of Mathematics, 2014a) through intellectually demanding tasks that illuminate the value of learning (Gresalfi & Cobb, 2011). In part due to the Mathematical Practice Standards (CCSS) and NCTM's Principals to Action (2014b), there is growing research using, aligning, and combining research in mathematics education and special education moving away from deficit focus to strengths-based focus on uncovering student thinking through cognitively demanding tasks and the mathematical practice standards (Xin et al., 2016). This guidance necessitates changes in mathematics instruction (Gonzalez, 2023; National Council of Supervisors of Mathematics & TODOS: Mathematics for ALL, 2016). However, change can be slow, and systems are resistant to change especially when those changes disrupt the status quo (Aguirre, 2022; Gonzalez, 2023; Gresalfi & Cobb, 2011; Martin, 2019; Tatum, 2017). Recognizing this change will require a deeper understanding of math instruction across all levels of the educational system and include purposeful professional learning and support to make those shifts.

It is important to reflect on how students are supported when changes shift notions around what math is, who math is for, or what math looks (Martin, 2000). These changes must not perpetuate or induce negative attitudes (Martin, 2000). To widen the view of mathematics and mathematicians, considering who is left out and expanding those who are portrayed can be done by reflecting on what stories are told and how communities and their knowledge are integrated within school systems (Gonzalez, 2023; Martin, 2000, 2019; Paris & Alim, 2017). Research suggests that "self-perception and confidence are core value assumptions that are expected to have an impact on students' achievement." (Bagger et al. 2020, p. 52). A shift that could change the focus for multilingual students where language and culture are viewed as a resource, again challenging the deficit mindset, as mastery of English doesn't determine mathematics understanding and proficiency (del Carmen Salazar, 2013; Robertson & Mellony, 2020). Armstrong (2010) recommends a similar shift by recognizing strengths in neurodiversity. By moving to a more pluralistic view opportunities open up for diverse students to engage in mathematics, inviting dialogue around what is normalized and valued as knowledge (Paris & Alim, 2017). There is a need to humanize mathematics education requiring paradigm shifts to supportable equitable instruction and justice in education practices and policies (Gutiérrez, 2013; Paris & Alim, 2017) requiring professional learning and shared understanding around instruction for teachers and administrators (Gresalfi & Cobb, 2011). Gutiérrez (2013) recognizes this can be done by looking at identity and goals in mathematics, including how marginalized students define "excellence" while embracing a "perspective that assumes that mathematics as a human practice can become more just" (p. 55)

Teacher Beliefs, Power, Identity, & Pedagogy

Given that mathematics serves as a systemic gatekeeper in schools, teachers must be aware of this and their role in making mathematics accessible to their students (Aguirre et al., 2013; Boaler, 2016; Gonzalez, 2023; Gutiérrez, 2013). Social norms, community expectations, and culture all contribute to the norms teachers face within schools and these impact classroom instruction (Leyva et al., 2021; Paris & Alim, 2017). Simultaneously, teachers have beliefs from their education (Miller & Shifflet, 2016), lived experiences, and interactions with students (Aguirre et al., 2013; Darling-Hammond & Oakes, 2019; Kolb, 2015) which shape their personal and professional identity, beliefs around mathematics, and their teaching as they navigate school and social norms (Paris & Alim, 2017). Teachers must balance the power dynamics, systemic expectations, demands, initiatives, and institutional identity with their own teacher identity (Gresalfi & Cobb, 2011; Roosevelt & Garrison, 2018).

Teachers reflecting on their own math identity, and their own narrative, is part of the conversation in research on intersectionality in mathematics (Guzmán, 2019) and is an essential exercise for educators (Martin, 2019; Tatum, 2017). The importance of reflection to consider one's own identities in relation to power, privilege, and opportunity has been noted in research (Crenshaw, 2016; Kendall, 2013; Minnich, 2005). "Identity has a profound effect on the teaching and learning of mathematics" (Gonzalez, 2023, p. 92).

Instructional practices built from a teacher's pedagogy, beliefs, and understandings, all directly or indirectly influence students' own beliefs, understandings, experiences, and opportunities to develop as mathematicians (Aguirre et al., 2013, Bagger et al., 2020). Interacting with students in a variety of ways including shifting away from teachers as knowledge providers and providing opportunities for every student to engage in discourse with peers will open space for students to participate, supporting not only their understanding of math but their sense of themself as mathematicians as well (Boylan, 2016). This is particularly important for those students who may traditionally have limits placed on them by society, by their access or lack of access to mathematics, and therefore limits on what they may do within and beyond the classroom.

Awareness and reflection on the part of teachers around stereotypes and bias provide the potential to engage in ways to open access for all students (Miller & Shifflet, 2016; Roosevelt & Garrison, 2018).

> In particular, the innateness of mathematics intelligence aligns with colorblind ideologies in mathematics to produce advantages for Whites. … This ideology (symbolic), coupled with racial achievement differences (material) in mathematics that are constantly reported in the news and academia, produces the racial hierarchy of ability. The achievement

> differences are material evidence that innate mathematics ability is not equally distributed by race. Therefore, a belief in innate mathematics ability serves as a colorblind way of unconsciously believing in the racial hierarchy of ability shaped by whiteness. (Battey & Leyva, 2016, p. 64)

Unconsciously, teachers can interpret "ability" as innate, relieving them of full responsibility in students' learning, and unconsciously applying more stereotypes to their students (Battey & Leyva, 2016). To integrate student's identities and knowledge, teachers need to recognize these dynamics of power and systems at play both in and out of school (Paris & Alim, 2017). Part of building relationships is learning about students; another part is considering how to respond to student's behaviors and uncovering the reason behind behaviors that might in fact be resistance (Martin, 2000; Paris & Alim, 2017).

By recognizing students' potential for growth and learning, rather than reinforcing beliefs of limited capabilities associated with fixed mindsets and deficit views, teachers see the possibility of growth for their students and not only what they are capable of in the moment (Roosevelt & Garrison, 2018). "Positive emotions and feelings of success during learning increase self-efficacy beliefs and motivation" (Hascher, 2010, p. 17) and are needed to be resilient and persevere when faced with failure or difficulty. Positive emotions allow for perseverance, to be re-engaged with learning, and to face mistakes, whereas negative emotions will increase withdrawal from failure (Hascher, 2010). Teacher's attitudes and reactions towards these mistakes and challenges influence how students react (Hascher, 2010) and how learners come to view learning as fixed or as an opportunity for growth (Boaler, 2016; Dweck, 2006).

Teachers establish values and set expectations for learners in their classrooms. If mathematics is not valued, or low expectations exist, it is challenging for students to develop a strong math identity (Hima et al., 2019). In contrast, when mathematics is valued in a classroom and students are valued, their strengths are recognized, and they are humanized by teachers, which aids in setting students up for success to overcome and resist labels and stereotypes (Aguirre et al., 2013; Martin, 2000; Paris & Alim, 2017). "In addition to equitable teaching strategies, such as collaboration and inquiry-based approaches, both girls and students of color – particularly underrepresented minorities – need thoughtful and positive messages to be given to them, about their valued place in mathematics" (Boaler, 2016, p.105). Messages received by students inform their self-identity and their attitudes and beliefs (Aguirre et al., 2013; Boaler, 2016; Hima et al., 2019; Smith et al., 2021). Children will rise to the level of expectations that teachers set for them, students will do more when they know their someone believes they are capable of reaching high standards with appropriate tools, support, and opportunities (Lambert, 2022.) challenging the myth that "math people" exist.

As Tatum (2016) suggests, another action educators can take to counter and resist stereotype threats is to provide examples and role models of academic achievement of people who share the student's identity. Counternarratives can provide multiple perspectives (Delaney & Mayer, 2021) and voices from marginalized groups which can support better instruction (Annamma & Winn, 2019) and equity (Guzman, 2019). Additionally, teachers who ensure that students are held to high standards, provide honest feedback, and make explicit that they believe in their students' ability to meet the high expectations the belief in a student is known to the classroom community (Tatum, 2017). Transparency around how learning happens and recognizing that knowledge and ability are not fixed but instead are malleable as learning and understanding grow over time has a positive impact on student's learning outcomes (Dweck, 2006; Tatum, 2017). In this classroom culture students have space for agency and positive mathematical identities to develop through collaboration, problem solving, and collective meaning making (Aguirre et al., 2013).

The Learners

Like teachers, learners are all unique individuals with various experiences, backgrounds, and knowledge sets entering the classroom. Perceptions of mathematics, and themselves as learners, contribute to students' attitudes and beliefs (Aguirre et al., 2013; Boaler, 2016; Hima et al., 2019; Keown & Bourke 2019). Paris & Alim (2017) point to the work of DuBois and the impact and role that "looking at one's self through the eyes of others" has on identity. Social norms, school, family, and peer interactions all impact identity development (Martin, 2019), see Figure 1, as well as how much of a child's identity they are willing to share in a particular environment. In the classroom, some students are given space to bring their full identity, while others are limited in what aspects of their true self they can represent (del Carmen Salazar, 2013; Paris & Alim, 2017). In the learning space identities should be intersectional rather than subtractive, and students should not feel they must hide themselves, lose their identities, or assimilate to the normative culture (del Carmen Salazar, 2013; Gutiérrez, 2013; Paris & Alim, 2017). Culturally sustaining pedagogies provide an opportunity to support student's full identities in and out of school, in contrast to an environment where students are seen as broken and needing fixing (Tan et al., 2019), this impacts the journey of identity development (Paris & Alim, 2017).

Learners' views and experiences, not only impact the space they may occupy in class but also their belief and recognition of possibilities that exist for them beyond the classroom (Hima et al., 2019). Bolar (2016) examines the impact of belonging to mathematical communities on learning and continued study of mathematics. The findings of the study showed that the fixed mindset, or fixed ability belief about mathematics, combined with the idea that men have more ability in math than women, left women feeling like they did not belong in mathematics; they generally had lower scores (Boaler, 2016). “Women who receive the message that math ability is learned were protected from the negative stereotypes – they maintained a high sense of belonging in math and remained intent on pursuing mathematics in the future” (Boaler, 2016, p. 96). Through their instruction, teachers play a role not only in students math learning but also in the development of students' mindsets, identities, persistence, and confidence (Aguirre et al., 2013). Negative experiences can contribute to negative feelings towards mathematics. Emotions create physical and behavioral responses that impact academic outcomes (D’Agostin, 2014) Learning is affected by emotions (Hascher, 2010); math anxiety physically affects the brain (Buckley et al., 2016) and is associated with negative attitudes, low confidence, and lower performance (Buckley et al., 2016; Jameson, 2014; Tomasetto et al., 2021).

Students experience stereotypes and cultural norms in different ways, and their reactions can range from developing identities to match stereotypes, to resisting such stereotypes, (Martin, 2019). Learners might disengage or exhibit disruptive behaviors to take on agency (del Carmen Salazar, 2013) or exhibit avoidance behaviors in relation to math anxiety (Garcia-Olp et al., 2017; Jameson, 2014; Tomasetto et al., 2021). Students who face marginalization navigate messages and negative stereotypes within school, often receiving labels which can result, at times, in being removed from classroom instruction. As previously noted, labels impact students' hope and their learning (Boaler, 2016; Dweck, 2006). Students are active in how they engage with resilience and act on their agency, students need a place to make these choices in the classroom especially when expressing an identity that counters peer groups and social norms is difficult in the face of the dominant culture (del Carmen Salazar, 2013; Martin, 2019).

Compliance and resistance, in many forms and through various behaviors, can be reactions of students to narrow norms and expectations in the classroom and how they may act to protect themselves in that environment (Aguirre et al., 2013; Martin, 2019; Paris & Alim, 2017). Encouragement, both at school and home, along with inclusion in the math class community where all student's ideas and knowledge are valued can have a positive impact and work to resist and counter negative experiences or stereotypes that students encounter (Keown & Bourke, 2019).

Students are not only resisting these messages from adults but at times facing differential peer treatment from peers for not conforming to norms or for demonstrating academic skills and setting goals (Martin, 2000). Fostering a safe environment for students to express their full identity and engage in meaningful ways (Paris & Alim, 2017) through choice (Tapper, 2012) supports student agency and positive math identity development. Additionally, when students are able to engage in a curriculum where they are represented, authentic connections to their lives and experiences are made, and applications to their community allow every student to see themselves represented and valued in mathematics (Childs, 2022; Gonzalez, 2023; Paris & Alim, 2017).

Students are also developing an understanding of what mathematics is, how it is defined, and what it looks like to be a mathematician. When a narrow view of math is held as calculations or memorization access to mathematics is limiting. If only a narrow representation of problem situations is used and not relatable to many students, access to mathematics is limited and limiting. When only a narrow scope of mathematicians is shown then students may not have the opportunity to see themselves or people sharing their identity as mathematicians. Research suggests that when we widen the scope and definition of mathematics students' perceptions change and more students come to like or enjoy mathematics more (Gonzalez, 2023; Hima et al., 2019). Students need to experience, explore, and engage in mathematics that is beyond calculations and numbers and includes the history and people who have made contributions to mathematics (Gonzalez, 2023; Hima et al., 2019). “Schools should be spaces where all students feel supported as their multiple identities evolve within a meaningful sense of achievement, purpose, power, and hope.” (Carmen Salazar, 2013, p. 142). When students have opportunities to see wide representations of mathematics students see themselves in the curriculum and give a purpose to stay in school (Paris & Alim, 2017).

Experiences in the math classroom can limit student’s views of themselves as mathematicians, leading to thoughts of “I can’t do this” “I don’t belong here” “I can’t do this, so I need to memorize steps.” When a narrow expectation is given, students easily can accept and fall into the false notion that they are “not a math person” (Boaler, 2016; Gonzalez, 2023). Every student deserves experiences to feel pride in their efforts, and opportunities to engage and recognize that learning is not without effort and productive struggle (Keown & Bourke, 2019). When teachers value student’s ideas and voice in the classroom, highlighting their ideas and contributions, they assign competence to the student which is especially important for students who may hold identities that may be marginalized (Boaler, 2016). When students have the potential to be seen and have their knowledge valued while engaging with tasks, they can embrace a growth mindset (Dweck, 2006). Students must know they are valued and expected to participate and engage in rigorous learning activities because when teachers or adults take away the challenge for a student, even with the best intentions, they are sending messages about the student's capabilities (Dweck, 2006). How a student sees their abilities and learning impacts not only their identity formation but also their academic progress and learning (Keown & Bourke, 2019). Research done by Gonzalez and colleagues suggests that math identity is a predictor of math success, GPA, in secondary school with a positive association (Gonzalez, 2023).

Students need to engage with mathematical practices, application, and conceptual understanding all of which require time (National Council of Teachers of Mathematics, 2014a), effort, and productive struggle. Collaboration and learning with peers are also an essential component of math learning for flexibility, conceptual understanding, and development (Common Core State Standards, 2010; National Council of Teachers of Mathematics, 2014a) will also impact math identity formation (Hima et al., 2019). Studies suggest that providing recognition and opportunities to engage and show thinking on tasks connected to their abilities and interests and working on problem-solving can shift views of mathematics (Hima et al., 2019) as students develop conceptual understanding and agency in conjunction with their mathematical identity. Positive experiences while engaging in problem-solving provide opportunities for students to form positive connections with math and can change math identity as well as ideas and beliefs about mathematics (Hima et al., 2019). A growth mindset supports success and the ability to face challenges and obstacles academically, crucial factors found in relation to a study on graduation rates of marginalized students (Keown & Bourke, 2019). As students' diversity is valued by teachers and peers, through a transformed curriculum that is connected to student's lives and experiences, it can not only support justice and provide representation for marginalized communities but also support positive math identity development (Gonzalez, 2023; Paris & Alim, 2017) and equitable access to this identity and math instruction.

Access to Equitable Math Instruction

Equity is a term used to describe a wide variety of justice-oriented issues: access, opportunity, democratic participation, and fairness; equity can facilitate participation, empowerment, and critique and transform injustice within education for all learners (DeJarnette et al., 2020; Ramis-Conde & Hope, 2020; Vomvoridi-Ivanovic & McLeman, 2015). Equitable math instruction includes access to challenging content, high-quality math instruction, and mathematical proficiency for all learners, in an environment that is responsive to students and understanding of their identities and backgrounds (National Council of Teachers of Mathematics, 2014a). High-quality instruction for deep learning includes expectations to explore and engage with rich tasks to build conceptual understanding, opportunities to be an active participant in the learning space, and being valued as a member of the learning community (National Council of Teachers of Mathematics, 2014a). The instructional environment can influence whether a learner comes to see oneself as a person who can do mathematics, embraces a growth mindset, and develops conceptual understanding along with procedural fluency that they can apply (National Council of Teachers of Mathematics, 2014a; The Hunt Institute, 2015).

Systems and Standards

Equitable strategies of mathematics instruction are important to consider if *all* students are going to be supported and able to participate in learning and discussions that build conceptual understanding. The focus of instruction in the mathematics classroom has shifted to include both content standards and math practice standards, or habits of being a mathematician (Huinker, 2020; National Council of Teachers of Mathematics, 2018; Robertson & Mellony, 2020). These content and practice standards necessitate moving beyond calculations alone to the development of learners as mathematicians with deep conceptual understanding who think critically and flexibly to problem solve, explain their thinking, justify their reasoning, and critique the reasoning of others (Boaler, 2016; Common Core State Standards, 2010; Huinker, 2020; National Council of Teachers of Mathematics, 2014a, 2018). Teachers are expected to teach these relevant and transferable skills, including collaboration and problem solving, that will serve students not only in their role as learners but also as citizens (Kolb, 2015; Mehta & Fine, 2019; Waks, 2013; World Economic Forum, 2020). Instructional elements, including intentionality of tasks, questioning, student engagement, teacher responsiveness, rigor, and expectations can be examined in terms of accessibility and equity for all learners (Huinker, 2020; Huinker & Bill, 2017; National Council of Teachers of Mathematics, 2014a). These elements allow knowledge to be constructed through inquiry and collaboration by the students as they make sense of their world (Ball, 2000; Darling-Hammond & Oakes, 2019; Delaney & Mayer, 2021; Kolb, 2015). Teachers foster this collaborative environment, build one each student's strengths, and teach in a student's zone of proximal development (Darling-Hammond & Oakes, 2019; del Carmen Salazar, 2013; Paris & Alim, 2017; Wink & Putney, 2002).When high-quality instructional practices are implemented, every learner can benefit from equitable collaboration and discourse (Hima et al., 2019; Lambert & Tan, 2020) engagement in rich tasks fostering a growth mindset (Boaler, 2016; Keown & Bourke, 2019; Woodward & Tzur, 2017), and access to effective instructional and responsive teaching practices (Delaney & Mayer, 2021; Tapper, 2012).

Teacher Practices and Instruction

Teachers create the classroom learning environment through their pedagogy and instructional moves. High-quality instructional moves are necessary for equitable access to math instruction. Deep learning theory recognizes three features: mastery, identity, and creativity, which are all situated within the community that is built over time (Mehta & Fine, 2019). For deeper learning to be successful, the teacher must establish relationships with learners, and space for peers to establish relationships which will allow for engagement (Ball, 2000; Kolb, 2015; Mehta & Fine, 2019). Teachers need to recognize, value, and understand the students in their classroom, their identities, culture, and the community in which they live in order to provide this rich learning environment (Gay, 2002; Roosevelt & Garrison, 2018) and humanize learners (del Carmen Salazar, 2013). Valuing the multiple aspects of a student's identities and working to understand more about students' cultures demonstrates the care teachers have for their students and provides essential insight needed to provide richer instruction (Annamma & Winn, 2019; Gay, 2002).

Teachers are making instructional decisions in part to meet standards and systemic and structural demands. Additionally, teachers enter classrooms with their own beliefs, mindsets, and identities, that interact with the expectations from systems and standards, influencing how they plan and implement instruction (del Carmen Salazar, 2013; Loughran, 2006; Miller & Shifflet, 2016). Reflection on biases and stereotypes is important for teachers to spend time doing, to consider their curriculum and materials and evaluate if they are culturally responsive (Gay, 2002). Personal reflection is equally important, as understanding oneself as a teacher allows for understanding how that impacts teaching. In one study, teachers reporting math anxiety used less effective teaching methods along with more surface level teaching, and less confidence in teaching math coexisted (Buckley et al., 2016). Furthermore, when teachers self-reflect they can consider their ideas around diversity and equity as well as the impact they have on pedagogy and understanding of their students (del Carmen Salazar, 2013; Loughran, 2006). This reflection heightens awareness of inequities and identifies areas for improvement, for example, the integration of social justice issues relevant to students providing them with skills to engage in thinking about change (del Carmen Salazar, 2013) through problem solving and application of math skills. "Mathematics teacher educators (MTEs) must also be willing to continually interrogate our/their work to identify narratives typically accepted as 'truth'" (Gutiérrez et al., 2023, p. 14). This intentional reflection on messages provides a way to interweave politics with content and pedagogy to not only identify a "harmful narrative" but also consider how to intervene to provide a "healthier narrative"; a key tenant of Political Conocimiento in Teaching Mathematics (PCTM) which allows for not only recognizing inequities but also understanding how systemic structures are interwoven in creating the inequities and then with that knowledge considering what steps to make toward change (Gutiérrez et al., 2023).

The curriculum, tasks, and stories in the classroom also matter as they offer representations of what mathematics is and who is a mathematician (Boaler, 2016; Gonzalez, 2023; Martin, 2000). Curriculum materials are created with a narrow scope of students fitting social norms based on white, cis-gender, middle-class experiences that may be unrelatable to all children and might not accurately represent what every student has had first-hand experience with (Gonzalez, 2023; Martin, 2000). In addition, the hidden curriculum can reinforce stereotypes and norms that may interpreted by students, as young as third grade as suggestions about the inferiority or superiority of some groups (del Carmen Salazar, 2013; Gay, 2002). What stories are told about mathematicians, what contexts are used, and the systems that allow or deny access to students are all based on societal perceptions, norms, and structures (Gonzalez, 2023). As contexts of problems, and application to various situations represent and imply values, teachers need to consider the curriculum, tasks, and opportunities they are putting out for their students (Gonzalez, 2023). "Learners will only experience joy, frustration, anxiety, pride, or satisfaction if the learning topic or the learning process is relevant to them" (Hascher, 2010, p. 14). Teachers' instruction can highlight the relevance and purpose of math, connecting learning to students lives (Childs, 2022; Martin, 2000; Paris & Alim, 2017) and expanding perceptions around what mathematics is and who mathematicians are (Gonzalez, 2023). Gutstein enacts social justice through a Freirean perspective by having students "read" and "write" using mathematics to understand the world around them through social justice issues to build or consider skills they have to impact the world (Gutstein, 2016).

"The value of PCTM is it provides a lens and a way of being in teaching that highlights knowing as a relation act (a verb) and reminds teachers to see mathematics, pedagogy, students, and politics as entangled, not separate parts that could be worked on individually" (Gutiérrez et al., 2023, p. 3). How teachers view mathematics, define being "good" at math, and how they see mathematicians influences how they represent and teach math in the classroom (Gonzalez, 2023). At times teachers' definitions around "good math teaching" is contrasted with the image held by administrators and the resulting tension leaves teachers to decide between doing what they believe is right or conforming to the institutional identity despite their beliefs and values (Cobb et al., 2009; Gresalfi & Cobb, 2011). For example, teachers knowing the importance of conceptual understanding and developing robust mathematical practices, as previously defined by deeper learning, may not teach in this way to conform to the institutional identity definition of "good teaching". Although educators are working within systems built on inequity that hold tensions, and at times differing expectations around "good teaching" (Gresalfi & Cobb, 2011) by using their agency to make decisions teachers can disrupt the systems for their students (Gonzalez, 2023). Teachers need to consider mindset and pedagogy in conjunction with content and curriculum (Keown & Bourke, 2019).

Access

Class culture, expectations of discourse, and a growth mindset help provide a safe environment for students to practice learning and communicating. Researchers used a critical perspective aligned with "…disability studies in mathematics education (DSME) principles and practices in examining ways in which students with intellectual disabilities are honored as mathematical doers and thinkers." (Tan et al., 2019, p. 1). This encapsulates the idea of valuing the voices of all learners while encouraging a strengths-based focus, growth mindset, and shift away from the traditional deficit focus. Fostering students' interest and engagement in learning is important. "The desire to learn, to participate in classroom interactions, is what motivates students to pay attention and to genuinely engage with their teacher/s in negotiating meaning to help make the input ever more comprehensible" (Robertson & Mellony, 2020, p. 87).

In the classroom, myths and beliefs commonly accepted in society and school systems can result in students not engaging with rich tasks, deep thinking, or developing conceptual understanding. For example, there is a myth that students must memorize facts before they can engage in problem solving, and another myth that lower expectations are better for students (Dweck, 2006; Martin, 2000; Paris & Alim, 2017; Xin et al., 2016). Students in the "low group", have less opportunity for discourse and are provided lower cognitively demanding tasks (National Council of Supervisors of Mathematics & TODOS: Mathematics for ALL, 2016). Making connections, engaging in problem solving and cognitively demanding tasks has been shown to be not only possible but valuable for all students, even if they haven't developed computational fluency (mastered their facts) (Bay-Williams & SanGiovanni, 2021; NCTM, 2023; The Hunt Institute, 2015; *The Myth of Low Kids and High Kids*, 2019).

Inclusive and collaborative learning environments that meet the needs of marginalized students, should be equity-based, providing learners a space to exercise agency, access supports, and be held to high expectations to collectively construct knowledge (Aguirre et al., 2013; Ball, 2000; del Carmen Salazar, 2013). Etienne Wenger-Trayner discusses their theory of social learning as "an account of learning as socially constituted experience of meaning making. The stance is to locate this experience in the relation between the person and social world as they constitute each other" (Farnsworth et al., 2016, p. 4). Deep learning necessitates learners are part of a community of meaning makers, can apply their learning, and recognize the usefulness of content in the world and their skills as useful for continued learning outside the classroom (Delaney & Mayer, 2021; Ladson-Billings, 2017; Mehta & Fine, 2019; Wells, 2000). To ensure access for all learners, teachers need to ask questions that support making connections between these ideas and to respond and guide learning while recognizing student knowledge and ideas (Delaney & Mayer, 2021; Mehta & Fine, 2019). Kolb (2015) suggests these objectives: content, learning style, and growth and creativity providing a way to respond and meet student needs. Access is a goal of social justice: determining what problems and tasks should be used impacts if learners are excluded or alienated from mathematics (Boylan, 2016).

Researchers have shown that teachers sometimes provide different access to conceptual understanding and rich mathematical experiences based on beliefs that they hold about different learner identities (DeJarnette et al., 2020; Ramis-Conde & Hope, 2020; Robertson & Mellony, 2020). "The detrimental effects of tracking start early in elementary school with readiness labels and ability grouping structures that provide vastly different mathematical experiences" (National Council of Supervisors of Mathematics & TODOS: Mathematics for ALL, 2016, p. 2). As an example, in one school, teachers were found to provide different learning opportunities to their multilingual learners (ML), giving ML's tasks with a low cognitive demand and in another instance only providing facts without any reasoning or explanation to ML's (Robertson & Mellony, 2020). Other research demonstrates how students from different racial and ethnic backgrounds experienced different questions from teachers. Black students were disproportionately given more retrieval "what" questions than their white classmates who were asked more "why" questions, while the Latinx students were asked fewer questions overall (DeJarnette et al., 2020). How the teacher interacts, asks questions, and provides wait time can limit, inhibit, or create opportunities for meaning making (Ramis-Conde & Hope, 2020).

The types of questions posed also shape participation in discourse. Questions provide or restrict access to participation during discussions which influences how learners engage, use reasoning, justify their thinking, and make connections as they grow as problem solvers (DeJarnette et al., 2020; Ramis-Conde & Hope, 2020). Research suggests that discourse is crucial to building understanding and allowing students to engage in mathematical conversations where they justify, explain, and reason about their mathematical thinking. When reviewing the data from one study, scholars noticed that some questions and redirections helped focus students on engaging in conceptual exploration, while other questions focused more on finding an answer without engagement in enough productive struggle leading to insight (Ramis-Conde & Hope, 2020). Another study showed how a teacher used questions to elicit students' thinking and respond in the moment to that thinking to engage the learner in meaning-making and use their understanding to solve problems (Xin et al., 2020). The study illustrates how this is done without telling the student what to do, but through posing questions and suggesting tools to allow students to make their thinking clear and has an impact on students being able to solve future problems (Xin et al., 2020). Research reinforces that it is essential for all learners to engage in rich discourse and be asked to answer robust questions to facilitate deep thinking about mathematical concepts (Yeh et al., 2020).

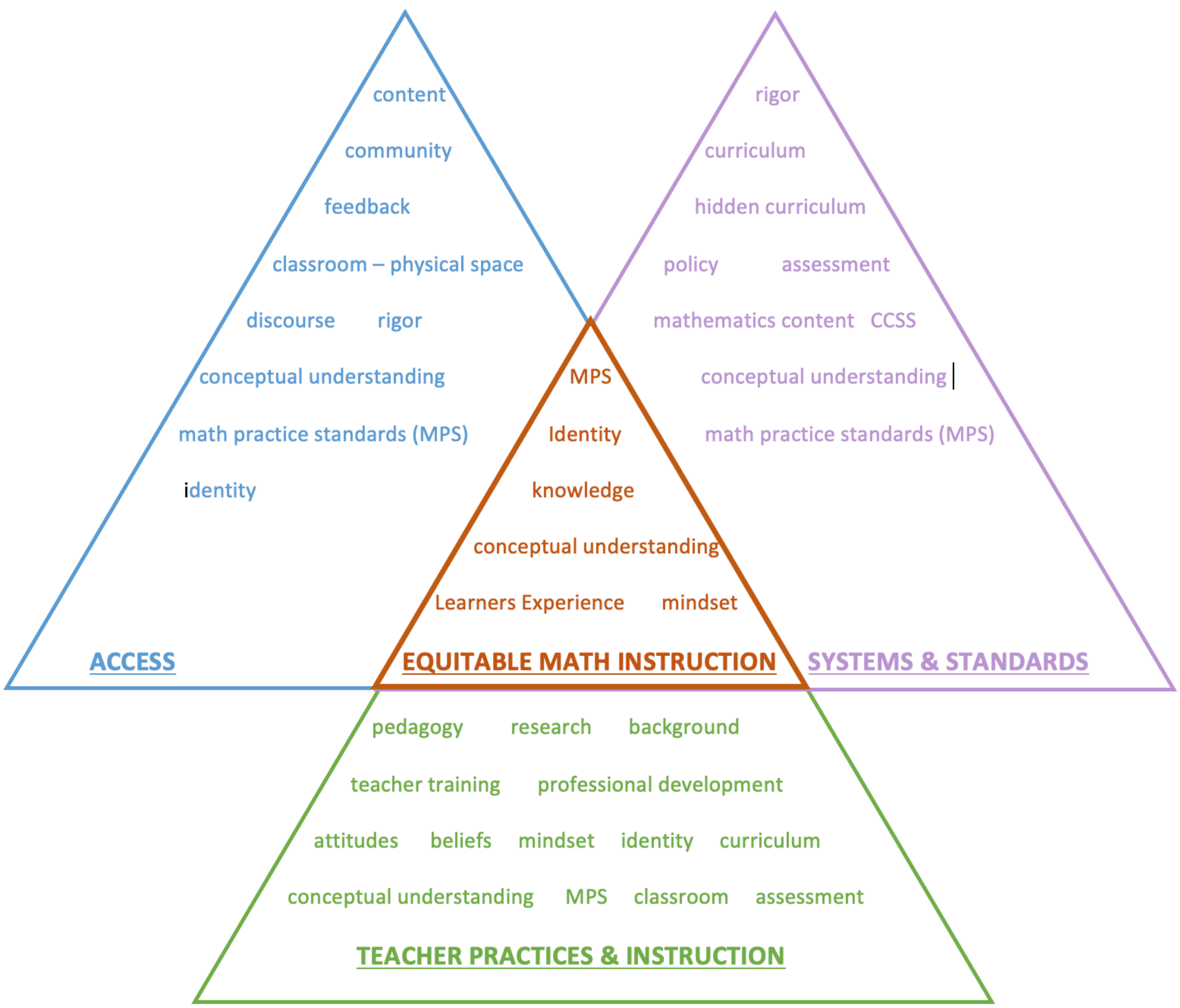
As the research discussed above helps to demonstrate, limiting students' access to inquiry based constructivist instruction can impact their access to conceptual understanding (Xin et al., 2016, 2020). In the United States, students' access to mathematics impacts the opportunities they have in the future including access to many majors in college and job and career opportunities thereby influencing socio-economic potentials (Bagger et al., 2020; Boaler, 2016; Tapper, 2012). Additionally, it impacts the opportunity to develop the skills to be engaged in a democratic society, use and apply math to problems in their world, workplace, and society (Kolb, 2015; Kuhn, 2008; Waks, 2013; World Economic Forum, 2020). Hence, it is imperative that all students to be provided opportunities to develop conceptual understandings, access to grade-level instruction, and not be restricted to only computation (Bowman et al., 2019; Lambert & Sugita, 2016). To this point, access to equitable mathematics instruction is crucial to meet the expectations from standards about content as well as habits of learning and is needed to prevent mathematics from acting as a gatekeeper and limiting students' opportunities in life. It is at the intersection of access, educational systems and standards, and teacher practices and instruction that provides the learners experience in a math classroom, as represented in Figure 4.

These experiences are informed by standards and expectations. Not only do these experiences impact knowledge and conceptual understanding but also mindset and identity. The importance of mathematical identity in learning is a significant element of equitable math instruction.

Figure 4

Factors influencing equitable math instruction.

Access, Teacher Practices and Instruction, and Systems and Standards are three sub-areas influencing and impacting equitable math instruction as noted in research(Aguirre et al., 2013; Boaler, 2016; Gonzalez, 2023; Leyva et al., 2021; Martin, 2000; Parks, 2020; Tatum, 2017). The diagram depicts how these subareas overlap, influence one another, and interact.



Summary

From experiences, in communities, within society, and at school, children develop their own beliefs and ideas around their identity as an individual and as a mathematician. It is through social interaction, experiences, and relationships with others that individuals' identities form and evolve over time. As the research suggests, it is imperative that educators consider how learners are developing their identity, specifically their math identity. Understanding the interactions between expectations and norms in society, at school, and in families as related and influenced by the classroom environment can provide a space for reflection on norms, biases, and impact that actions have on math identity and learning. Maintaining a focus on positive experiences, rigorous expectations, and working to make mathematics accessible for all learners are some aspects to recognizing, respecting, and humanizing learners and fostering positive mathematical identities.

It is in spaces which foster and strive to support positive math identities that students will have more support to embrace this identity for themselves. Reflecting on their experiences, the messages received from teachers, at school, at home and from their community and greater world will be important for students. This is also key to allowing learners to consider multiple possibilities for their future selves, to not be limited by a lack of understanding or an untrue belief that they can't or shouldn't take on something that might involve mathematics. Recognizing and pursuing interests will allow opportunities to remain open for learners and a positive math identity is essential to learners believing they are capable of learning and growing to achieve their goals.

Mathematical identity awareness as younger learners develop their identities can be powerful. This is a potential shift from only examining older students' math identity or reflections back on learning as an adult. It is relevant to educators of younger learners to raise their own awareness not just of their personal attitudes and beliefs, but in consideration of how they create their classroom environment to be aware of how they support, and could further support, their learners. Awareness and discourse about math identity are needed to make systemic changes or to succeed with reforms to disrupt the current inequities and increase access for learners.

This awareness is also critical as the research presented correlates math identity with the actual learning of mathematics, as shown in Figure 2. The beliefs, attitudes, and emotions impact how learners engage, or disengage, with the actual learning itself. It influences if they see themselves as capable of learning, or if they have negative thoughts about mathematics, the value it has in their life, or the need to engage with it. Emotional reactions can inhibit learning and recall of information, both of which are essential to engage with deep learning and develop skills to meet rigorous standards or to engage in a global world.

Preparation to be engaged citizens with skills to problem solve and enact change also necessitates consideration of equitable math instruction. Critical reflection on systems and structures, accompanied by understanding the influences and norms that are the foundation for them provides a way to name and work to change the inequities. In the smaller sphere of the classroom this includes teacher self-reflection to check bias and beliefs as those influence not only student identity formation but the instruction they provide to their students. Teachers must navigate their values and pedagogical beliefs with the system expectations, and if there is a mismatch determine how to do right by their students. Teacher reflection also can reduce differential treatment in terms of opportunities for students with labels based on stereotypes or bias, knowingly or unknowingly, that can be perpetuated in the classroom. This could look like access to tasks, discourse, or deep-thinking questions for their students. It also could include critical evaluation of curriculum to reduce the implicit bias that exists in curricular tools and incorporate social justice into the instructional materials itself.

All of this impacts the learning in the math classroom. This is the learners experience in school. It is affecting how they relate with the world around them, their community, family, and peers. The opportunities influence their understanding and development of learning as well as their formation of mathematical identity, both of which require focus to work toward equity.

CHAPTER THREE: Methods

A Critical Lens in Research on Equitable Math Instruction

A growing number of studies in mathematics education have focused on identity including who is included and disrupting myths about math learners while focusing on the quality of their experiences (Chronaki, 2017). This strengthens work toward justice for the inequities that exist for students based on logics, cultural norms, power dynamics, and systemic inequities founded on gender, race, and dis/ability (Mao et al., 2016; Yeh et al., 2020). Not only is consideration on making mathematics equitable needed but additionally considering how mathematics can be used in social justice and equity is needed (Gutstein et al., 2005). "Equally important, a social justice stance interrogates and challenges the roles power, privilege, and oppression play in the current unjust system of mathematics education – and society as a whole" (National Council of Supervisors of Mathematics & TODOS: Mathematics for ALL, 2016, p. 1).

Ongoing critical reflection throughout the research process can help researchers become more aware of relationships and power dynamics (Mao et al., 2016). A Freirean perspective necessitates focusing on positive change and justice to counter oppression, abuse of power, and privilege (Freire, 2000; Zhao et al., 2022). In one teacher-focused study, researchers presented a case where instruction that focused on identity, recognition of and reflection on socio-cultural and historical influences and norms allowed the teacher of a self-contained classroom of students with moderate to severe disabilities, to embrace and recognize the knowledge and strengths of her students and see their multiple identities (Yeh et al., 2020). This study highlights features of equitable math instruction, showing students with dis/abilities being held to high expectations, given space to engage in meaning making and time to discuss and justify their reasoning (Yeh et al., 2020). This research challenges the prevalent deficit mindset and ableism by using critical pedagogy and critical disability studies to focus on instruction that resists bias and allows for all students to access deep conceptual understanding (Yeh et al., 2020). A critical approach humanizes the learners, valuing their perspectives, and recognizing the impact from external factors including the impact of society and history on their identity and their learning (Haney et al., 2004; Yeh et al., 2020). Rather than focusing on gaps and making students the same, a sociopolitical focus in mathematics provides a focus on "knowledge, power, and identity as interwove and arising from (and constituted within) social discourses" (Gutiérrez, 2013, p. 40).

When a critical approach is used in research, it provides space for the incorporation of experiences and questions that center the participants' perspectives to understand the experiences of others referred to as the "verstehen" (Allison & Pomeroy, 2000) and recognizes children as experts of their experiences (Søndergaard & Reventlow, 2019). "Design thinking calls us to be curious, to ask and listen, to assume we don't know about someone else's lived experience" (Imm et al., 2024, p. 122). Having students' voices centered in research about the development of equitable instruction can provide additional perspectives, ideas, and considerations to open up access for more learners (Imm et al., 2024). Allison and Pomeroy note "Somehow the experiences of individuals that are so central to our work are lost when it comes to research." (2000, p. 97).

Allison and Pomeroy (2000) call for shifts in research on experiential education, with two important goals being "developing understanding" and generating thick descriptions which provide as much detail as possible in the triangulation of multiple data points of mixed methods research. Everyone within the same learning environment will have different responses and experiences based in part on their previous experiences, family and community influences, as well as relationships and identities they hold personally and within the classroom (Aguirre et al., 2013; Gonzalez, 2023; Keown & Bourke, 2019; Martin, 2000). "…[A] focus on identity and power is appropriate for understanding and improving the conditions not just for marginalized students, but for all students" (Gutiérrez, 2013, p. 49). It is essential that all stakeholders and participant voices are represented so deeper understanding can occur as more stories are told.

Related Theoretical Frameworks

Notions about learning and how knowledge is created place value on individual's experiences and perceptions as data points in research. Learning is a social process; interactions, relationships, and communication are all components of learning (Farnsworth et al., 2016). To capture this idea of social constructivism, considering an experiential approach to teaching is and building on ideas from "Dewey and the American pragmatists proposed that the only ultimate reality is experience" (Allison & Pomeroy, 2000, p. 92). The social learning theory work of Wenger recognizes learning extends beyond the curriculum and is done socially to understand content but in the process, individuals are learning about and creating their identities as they negotiate learning in different environments (*18 Questions on Social Learning Theory*, 2010).

This is aligned with identity theory which considers roles and identities and recognizes how identities are formed by social interactions. "Identity is the pivotal concept linking social structure with individual action; thus the prediction of behavior requires an analysis of the relationship between self and social structure" (Hogg et al., 1995, p. 257). As interactions occur, they shape behaviors, in relation to one's identity and beliefs, with continuous changes and identity based on environment and situations (Gutiérrez, 2013). "For instance, identity theory focuses on the process of labeling oneself as belonging to a particular social category, acknowledges the role that others may play in supporting this categorization, and relates self-concept to behavior via behavioral prescriptions and embodied roles" (Hogg et al., 1995, p. 263). Identity theory recognizes that multiple people and factors impact identity.

Mathematical identity, as defined by Martin (2000) includes recognition and reflection on the various intersections that impact identity formation both in small local contexts as well as the factors at a wider context. Martin situates identity development within several levels of influence, including the sociohistorical level, the community level, the school level, and the interpersonal level. Within and across these levels, interactions with people in the community, at the home, and at school all shape students' identity formation, as shown in Figure 1. The same influences on mathematical identity are impacting emotions, namely "teachers, peers, family, learning material and so on" (Hascher, 2010, p. 18). Each influence bears a different weight, or significance of impact, on learners emotions (Hascher, 2010). The social learning experiences, interactions and collaboration occurs with different people, and emotions are very tied to "self" (Hascher, 2010), in other words identity. Theories on emotions accept three ideas; emotions are a reaction which can be described, emotions are experienced when a context is meaningful, people are self-aware of their emotions but can hide it from others (Hascher, 2010).

Emotions are not the only aspects of self and identity that can be kept hidden. Environment and social situations may determine which aspects of identity students will reveal and which they will hide (Cobb et al., 2009; Martin, 2000). Community and culture define or normalize a particular image of a math student and those logics or norms are what students are compared to or compare themselves to when they reflect on their math identity (Aguirre et al., 2013; Cobb et al., 2009; Gresalfi & Cobb, 2011; Leyva et al., 2021; Martin, 2000). The influence of other people on a student's math identity development is not limited to adults because relationships with peers and classmates also matter (Martin, 2000). In Martin's research, interviews of students and parents revealed stories of relationships with mathematics which have been influenced by experiences, teacher expectations, and social messages (Martin, 2000). These interviews demonstrate instances when learners embrace a positive math identity and work for deep understanding to counteract a negative belief they face. The interviews also tell stories of how parents' experiences as students now have an impact on their interactions and expectations around their own children's school experiences with mathematics. Interviews showcase narratives of people's experiences and the various pathways that learners follow to resist or embrace the beliefs and stereotypes they encounter (Martin, 2000).

Racism, classism, and ableism contribute to deficit thinking and values that are portrayed in society and awareness of local histories and lived experiences of students is needed to recognize and resist systems of oppression (Annamma & Winn, 2019; Martin, 2000). Martin (2000) recognizes it is vital to consider historical context on individuals and community as they effect mathematical identity within which these interactions are taking place. Examining the sociohistorical background provides insight into cultural norms, and looking at how students respond to those norms provides insight into their math identity development.

Influential Research Methodologies

Drawing on arts based research which "recognizes that the use of arts is critical in achieving self/other knowledge" (Leavy, 2017, p. 195) along with identity theory aligns with an experiential approach to learning and social constructivism (Abdulah et al., 2021; Hogg et al., 1995; Søndergaard & Reventlow, 2019). Arts based research also recognizes "bodies" or people are influenced and shaped by history, values in society and aspects of identity including ethnicity, class, gender etc. (Leavy, 2017) which is aligned to the influences key components of mathematical identity (Martin, 2000).

Vulnerability in reflecting on one's mathematical identity is complicated for both adults and children. Arts-based research utilizes art to elicit thoughts and experiences from participants which for some participants can be an easier way to communicate ideas (Abdulah et al., 2021; Søndergaard & Reventlow, 2019). Math can be connected to feelings of anxiety (Boaler, 2016; Buckley et al., 2016; Jameson, 2014; Tapper, 2012; Tomasetto et al., 2021) so expressing ideas around mathematics in drawing may feel easier and less threatening than verbal responses or responding to interview questions allowing learners to have control over communicating ideas which might be difficult to articulate verbally (Haney et al., 2004; Weber et al., 2011). The use of drawings for students to communicate ideas and reflect on difficult topics has proven to be a strong communication tool (Søndergaard & Reventlow, 2019; Weber et al., 2011).

Incorporating different sources of data and modalities provides space for children with different communication styles to have ways to express their knowledge and experience, and incorporate details through their words (written or spoken) (Søndergaard & Reventlow, 2019) "Research in mathematics education research broadly tends to emphasize verbal interactions" (Parks, 2020, p. 1444). Using drawings offers a different approach to what is typical in math education research and also supports making participation more open to diverse students with dis/ability, language, or communication differences as a way that confirms all learners' voices are valued in the research (Haney et al., 2004).

Engaging students in reflection by creating drawings provides space for every student to participate, including those who might be quiet or on the periphery during class, and therefore represented less in other types of research, to be represented in this data (Parks, 2020). Utilizing drawing also helps to balance the power between children and adults (Haney et al., 2004). This capitalizes on students skills to communicate in this "unique language" (Weber et al., 2011).

This reflection on the power dynamics at play in research aims to allow the focus to remain on the learner's experiences in a manner that is not threatening (Mao et al., 2016; Weber et al., 2011; Zhao et al., 2022).

Drawings provide a tool to "…gain insight into how children view the social world, and as a way to learn about the world(s) in which children live." (Gamradt & Staples, 2023, p. 37). Drawings can capture experiences, moods, and feelings (Søndergaard & Reventlow, 2019) and are a developmentally appropriate way to engage with younger learners in research focused on their views and experiences (Gamradt & Staples, 2023).

As has been done in research involving photography, considering what the focus of the drawings are provides important information to consider what elements of math instruction and classroom activities are included and which are left out (Metcalfe, 2015). In their analysis of research Metcalfe (2015) studied how the contrast and juxtaposition from one image to another could be used in coding as another way to analyze visual images, or to considers what changes are happening over time through analysis of visual portrayals and reality. Analysis of and comparison of the visual to text, or visual to interpretations provides another aspect to meaning making (Metcalfe, 2015). In some instances the drawings can be considered in providing information on learners identity and racialization through the color, or lack of color, used in their drawings (Metcalfe, 2015). This approach contributes to "student-centered insights about concrete examples of practices that positively and negatively impact historically marginalized students." (Leyva et al., 2021, p. 809).

"… [S]tudent drawings are not only a simple and powerful way of documenting the educational ecology of classrooms and schools, but also a potentially powerful tool for reflection and change on the part of teachers and students" (Haney et al., 2004, p. 246), and are therefore a powerful tool in critical framework of research. Reflexivity is built into the research process to monitor and consider how power dynamics, cultural influences, identities, and personal experiences are impacting the research, from focus to analysis (Mao et al., 2016; Zhao et al., 2022). The use of student drawings in mathematical research and to reflect on the voices of learners a necessary element to critical research (Zhao et al., 2022). This critical orientation is focused on positive change and justice highlighting the unequal systems and recognize oppression, power, and privilege (Freire, 2000; Zhao et al., 2021).

Drawing On Math Tool

Analyzing a decade of research focused on student drawings that were used to document what is happening in schools, Haney and colleagues (2004) drew on their experiences and the work of Russell (1999) and Gulek (1999) to support the validity of gathering data through student drawings as construct evidence and construct validity. Researchers have also used in “Draw a Scientist” and “Draw a Mathematician” when examining the perceptions held around math and science, and uncovering stereotypes and bias through analysis of drawings (e.g. Picker & Berry, 2000; Weber et al., 2011). While drawings tend to be limited in educational research, this study recognized the power of drawings as a tool that can be implemented more systemically capturing more voices and having greater reach than observations or interviews (Haney et al., 2004)

In the work from Haney and colleagues (2001) validity was established through convergence of evidence; classroom videos were more highly correlated with the drawings than survey results. Additionally, there were connections between what students reported and what was depicted in their drawings (Haney et al., 2004). In one study drawings were administered and coded four weeks apart, given similar trait scores over time supports stability of the results of drawings as a valid method (Haney et al., 2004). Multiple coders were used as coding was developed and revised to develop detailed characteristics for coding that were "reasonably good" based on Cohens Kappa analysis (Haney et al., 2004). These points of establishing reliability and validity are, "… indicating that drawings can be used to document real aspects of classroom life and students' practice." (Haney et al., 2004, p. 263).

Furthermore, consequential validity was established when drawings were used for holistic review with teachers and were found to have an impact on school reform (Haney et al., 2004). When the drawings are viewed collectively it is possible to consider patterns and avoid ranking or comparing individual learners representation of their experiences, and can tell a group story (Gamradt & Staples, 2023). This supports reflective conversation on teaching, based on student's descriptions of their experiences which is not the same conversation when reviewing assessment data (Haney et al., 2004). Patterns across drawings is a stronger way to look at the data over individual drawings taken alone when follow-up conversations with the learner are not possible to bring more clarity to their meaning (Haney et al., 2004) and can be accomplished through holistic coding of drawings.

Research Design and Method

This mixed methods study is designed to explore the perceptions of elementary students in learning mathematics in elementary school. Being "problem-centered" mixed methods research (Leavy, 2017) is a powerful way to examine the issue of equitable mathematics instruction. Not all students have equitable access to an environment that promotes and supports the development of positive math identity and/or to deep conceptual understanding (Aguirre et al., 2013; Boaler, 2016; Gonzalez, 2023; Martin, 2000, 2019). To better understand the identity that is being formed it is necessary to ask children themselves (Martin, 2000). Through learner's reflections of what learning math looks like insight is gained into the lived experience of students (Zhao et al., 2022). Integrating arts-based methods for coding and data analysis along with a critical lens to connect to identity theory as perceptions and experiences are critical components of building a mathematical identity. Mixed methods allow the data to be examined both quantitatively and qualitatively.

The Brocksburgh School District (BSD) (pseudonym) conducted a math review which included surveying students on their math experiences and incorporating teacher surveys throughout the year. The student surveys were conducted in the fall and were done as a drawing prompt from “Drawing on Math”. Data from three elementary schools in BSD provided a set of 348 drawings which are the basis of this study. First the drawings were coded using the codebook (see appendix B). Quantizing transformed the codes into quantitative data that allowed for comparison of the presence or absence of characteristics in the drawings (Leavy, 2017). Codes from “Drawing on Math” (Reflective Education Research, n.d.) were used as that was the source of the math drawing survey prompt that the district used (see appendix A and B). This quantitative form of data was used to explore learners’ experiences, and answer research question one. This data was also analyzed for similarities and differences in drawings of younger elementary students (grades K-2) and older elementary students (grades 3-5), research question two. Research suggests that math attitudes can decline around grade 3 and this is when attitudes more strongly become predictors of performance (Dowker et al., 2019; Ganley & McGraw, 2016), given this information the comparison of the grade bans looked at the data to see if there were differences represented in attributes of the student drawings in older and younger students. The trends in drawings and numbers of types of math and elements in the classroom were considered in relation to the defining features of mathematics that teachers identified in survey data (see appendix C), an opportunity to consider these data points and connections (Metcalfe, 2015) to inform research question three.

After completing quantitative analysis, qualitative review of drawings was done for a subset of the data. While all drawings were coded and analyzed quantitively, looking more deeply at a subset of drawings individually unpacked details in the experiences that were not evident in the numerical data. Following patterns or unique cases as evidenced in the quantitative data, particular drawings or sets of drawings were reviewed for more information about the features and characteristics depicted. This provided insight into the patterns, uncovering similarities or differences among the drawings based upon details or features depicted. While the quantitative analysis provides information about a big group and general trends and information resulting from multiple perspectives, this provided understanding through the details.

A closer exploration of a subset of the drawings allowed more depth of a learner's experience to be shared. Descriptions of eight drawings provided details about how the learners represented math class including any words or captions they wrote. Criteria was established before reviewing data outlining a process for selecting drawings that would be used to tell individual stories. This incorporated student's words with their drawings to consider their experience in math class.

Consideration of how the learners documented their classroom environment is one factor that is influencing their mathematical identity. "This is not just about understanding students' identities in some kind of developmental, linear trajectory, or deterministic manner. It is about how identities are (re)constructed in spaces and moments" (Gutiérrez, 2013, p. 39). Sociopolitical and critical frameworks support research examining the norms, logics, and power dynamics at play within these spaces (Gutiérrez, 2013). This knowledge also strengthens work toward justice for the inequities that exist for students based on logics, cultural norms, power dynamics, and systemic inequities founded on gender, race, and dis/ability (Mao et al., 2016; Yeh et al., 2020). Research is growing with awareness around identity and math education, focusing on who is included, disrupting myths and beliefs about math learners while focusing on the quality of experiences (Chronaki, 2017). A critical approach humanized the learners, valued their perspectives, and recognized the impact of external factors including the impact of society and history on their identity and their learning (Haney et al., 2004; Yeh et al., 2020). Adding learner perspective to the conversation on mathematical identity development and math class experiences is done with a goal of transformation or change, an essential aspect of critical and sociopolitical frameworks (Gutiérrez, 2013).

Research Location

The data came from Brocksburgh School District (BSD) (pseudonym), a midsized suburban school district serving approximately 4000 students in Pre-K through grade 12 in the North East (IES National Center For Education Statistics, 2022). The Education Agency of the State reports the student population is just over 80 % white, with just under 20% of students identifying as BIPOC (Black, Indigenous, person of color) or more than one race. The Education Agency of the State and State Fiscal Office report just under 5% of the population are English Learners, and just over 20% qualify for free and reduced lunch. The Education Agency of the State also reports that just under 5% of the student population are on a 504 plan and 4% on an Educational Support Team (EST) plan.

This study used existing data collected as part normal educational practices in BSD. The district hired a professional development organization to complete a math audit in providing staff and students with surveys and interviews. The district plan in the fall of 2023 included student and staff surveys, as recommended in the math audit, as well as professional learning and systemic conversations on instruction and intervention. These results and artifacts became the data for this research study (see appendix C and D). This data is anonymous. As students completed their drawing surveys some included names, to protect their identity when the survey results were reviewed and used within the district all student names were redacted by a district staff member prior to analysis.

Data Sources, Procedures, and Tools

Data Collection and Tools

BSD used a drawing survey to elicit students' perspectives on their experience in math class. Elementary students responded to the prompt "Draw a picture of your math class". BSD also routinely collects teacher survey results that provide information on teachers' ideas around mathematics, understanding and value of the districts math vision and resources, and feedback on professional learning opportunities. Student drawings and teacher survey results (see appendix A-D) were the two sources of data and were examined in conjunction with the literature. The data provided examples of using drawings as a tool with students across elementary grades focused specifically on "schooling and learning" (Haney et al., 2004).

Drawings were done in the BSD elementary schools as part of the district's work to survey students about their experiences in math class (see appendix A and B), as was outlined as a next step in the math audit that had been completed in the 2022. The drawings were copied with any student names redacted by a district staff member so that when data was compiled and shared with staff there was not any identifiable information. All the redacted drawings were coded, and the quantities of each attribute became the data for quantitative analysis. The quantitative data provided a look at the community of learner's experiences and provided a way to analyze similarities and differences between grade spans and teacher vs. student factors to provide information for the research questions. To elaborate and explain some of the trends or unique cases in the quantified data, qualitative analysis of the drawings provided information, insight, and descriptions of learners' experiences.

To move beyond this explanatory sequence further qualitative analysis of individual experiences was obtained from within the original data. Purposeful sampling was used to intentionally "selecting cases that show different perspectives on the problem, process or event" (Creswell & Poth, 2018, p. 100) for qualitative analysis. This provided the thick description (Allison & Pomeroy, 2000) and individual narratives to answer *What are different ways students perceive and express their experiences in math class?*, the first research question. As the goal is to offer individual perspectives, criteria were established that would provide positive and negative emotions and allow the most insight into the student's experience. The plan was to select five drawings using purposive sampling to provide extreme or deviant sampling (Creswell & Poth, 2018; Ritchie et al., 2013). Extreme sampling allows stories from learners with both positive and negative emotions to be showcased and to contribute both perspectives in this research. The criteria for selection were:

- the student is in third grade (fourth or fifth grade if needed)
- there are people in the drawing
- the student wrote words beyond labeling objects in the classroom
- the depiction is clearly positive or negative on the analytic coding of student attributes

The criterion of people in drawings was set to show the student and their experience and see what emotion(s) were represented on their face. The criteria of words written by the student was set with to provide more insight from the learner's perspective and require less interpretation of the drawings as they are anonymous and member checking cannot be used. Third grade was chosen because in growing research exploring math attitudes and performance has found that math anxiety, negative reactions/worry, and interest were all attitudes identified as predictors of performance in third grade, but in first and second grade not all three attitudes were predictors (Ganley & McGraw, 2016). Additionally, research suggests a general trend in positive attitudes about mathematics decreasing over the years during childhood, often seen in secondary school. (Dowker et al., 2019).

In using this criteria, 13 drawings from third graders that had words and descriptions about emotion and feelings written on them pulled for consideration. Five drawings met the criteria. In the remaining drawings, some of the positive depictions did not fit the criteria of having a person with emotion clearly represented, or they showed the back of someone's head again. One drawing with positive words had a chair labeled "me", in another student wrote "I (heart) math" but all students were drawn without discernable faces/emotions. As there were not any positive drawings meeting the criteria in grade three, review of fourth and fifth grade with this criterion was done. In fourth and fifth grade the only written words were negative – "stress", "This is too hard", "Confusing" etc. Therefore, to establish and portray the extremes, the three drawings from third grade with clearly written positive messages but not with students depicted showing clear emotions, were included to provide the balance and representation of both emotions. An important aspect in research is to study not only negative emotions or math anxiety but to include positive attitudes towards mathematics as well (Dowker et al., 2019) and is a reason for sampling with maximum variation (Creswell & Poth, 2018) and the rational for including the drawings where students were not visible or had undiscernible emotions.

The final data set was teacher survey results (see appendix C) which had been conducted routinely within the BSD. Brocksburgh District summarized and graphed teacher survey data for use in district planning and decision making. Results from two questions, “What is math?” and “How do you feel about math?”, were selected for data points as they were focused on emotions related to mathematics, as a checklist, and the other on what mathematics is, as an open response question. This survey data was juxtaposed with the quantitative data from student drawings to answer the third research question, *What are some of the visible elements of math class are portrayed by learners align with or differ from the elements of mathematics named by teachers?*

Data Analysis

The redacted drawings themselves were the primary source of data. The redactions ensured that the data was identifiable by anyone viewing the drawings including the researcher or the additional coders used to check consistency of the coding. Due to the student-centered approach of this district survey, the data was selected for this study as they offered learners perspectives of math class. These perspectives will add to the limited research that exists around younger learners’ voices (Parks, 2020). All available redacted drawings were included to incorporate as wide a range of student perspectives as possible.

Coding a larger collection of drawings and examining them quantitatively allowed for more information on the experience of elementary learners in mathematics than qualitative alone. This numerical data was then explained through looking at the individual drawings to better understand the numbers of attributes as they related to learners’ experiences (Leavy, 2017). The full qualitative analysis more deeply explored a smaller set of drawings to tell more of the learner’s individual stories. In this mixed method study where the data was embedded “*one dataset is nested within the other for support”* (Leavy, 2017, p. 176). This is in line with the complimentary nature of mixed methods both methods offer something that the other does not provide, "quantitative research provides an opportunity for generalization and precision; qualitative research offers an in-depth experience of individual perspectives" (Creswell, 2014, p. 15).

The prompt "Draw a picture of your math class" has been used in research and has a coding system that was developed to highlight features of students' drawings (Haney et al., 2004). Given that this has been used over time by researchers such as Dr. Bebell in his work with school districts through the Reflective Educational Research (Reflective Education Research, n.d.), the codes served as a codebook of a priori codes for analysis of this data (Crabtree & Miller, 1999). This analytic coding systems provided drawing characteristics as well as operational definitions to support consistent coding and data for quantitative analysis. A list of codes organized by categories, along with descriptions of each code, example drawings and how they were coded based on these criteria, provided the three elements required in a codebook; namely the code label, defining criteria, and examples of coding (Creswell & Poth, 2018).

Patterns across drawings was a stronger way to look at the data over individual drawings taken alone because follow-up conversations with the learner were not possible to bring more clarity to their meaning (Haney et al., 2004). When the drawings were viewed collectively it was possible to consider patterns and avoid ranking or comparing individual learner's representation of their experiences, to tell a group story (Gamradt & Staples, 2023). Quantitative analysis afforded the opportunity to see patterns and trends regarding the research question *What are different ways students perceive and express their experiences in math class?* Chi-square tests were used to consider differences in grade spans, K-2 and 3-5, as well as during the triangulation of data with teacher survey results. The qualitative analysis of selected drawings provided snapshots of individuals experiences communicated in their drawings. This combination of more detailed individual descriptions alongside the trends and observations about a larger group integrated multiple data points and supported developing understanding of experiences in building the thick descriptions (Allison & Pomeroy, 2000). Then this quantitative data was arranged by grade bands to explore the question *What are the similarities and differences in math class experiences in early elementary (K-2) in comparison with upper elementary (3-5) as portrayed by the learners?*

Additionally, comparison between the defining characteristics of math as identified by the teachers and the components of math class depicted by students addressed the research question; *What elements of math class are portrayed by learners align with or differ from the elements of mathematics named by teachers?* The summary and analysis of the teacher survey was considered and compared to the characteristics and components of math class represented in the drawings. Similarities between the teachers' ideas of math and the experience of learning math from the learner perspective were noted.

Validity and Reliability

As existing data was used, steps were taken to ensure that coding the drawings was as accurate as possible. The codebook (see Appendix B) is a valid and reliable existing tool that was used to complete the coding for the quantitative analysis. External coders were used to establish interrater reliability to check interpretation and use of the codebook for reliability and coder agreement to consider the validity of data analysis (Belotto, 2018; Creswell & Poth, 2018; Leavy, 2017). The plan was for two independent coders to code 10 drawings each, compare codes, and repeat two more times looking for 80% or more agreement on the codes. There was an opportunity to have a third coder for increased reliability.

Sixty drawings were pulled randomly to be coded and compared to external coders for interrater reliability. Sets of ten second, ten fourth, ten third, and ten kindergarten grade drawings were made, as well as two different sets of ten drawings with representation from all grade levels. The second, fourth, and one mixed set of drawings were chosen and compared with coder one. The third, kindergarten and second mixed grade level set was created and used for comparison with coder two and three.

The researcher and coder one looked at the first set of drawings and coded them independently which resulted in 93% agreement. Upon looking at the agreement across categories, **student desks in rows/grids** was the category with the most differences as 7 out of the 10 drawings were not in agreement. The researcher and coder one reviewed the coding description and recognized that the discrepancy was because different components of the code definition had been focused on. Discussing the descriptors of desk touching/tables, implying shared working spaces, vs. grid/ desk in rows and considering what to do about drawings that did not show multiple desks. Based upon the review of the codebook, definitions and first set of drawings, it was agreed upon that if there was one single desk there wasn't an indication of shared workspace it would fall under the latter but if there were multiple chairs or desks grouped and touching it would fall under the former. This decision was supported by the parenthetical notes in the codebook **Student desks clustered** with the note "(typically desks or table(s) touching)" and **Student desks in rows/grids** as "(desks or tables typically not touching)" (Reflective Education Research, n.d.). This process was repeated with the remaining two sets of ten drawings. The second set had 96% agreement and the final set had 93% agreement. All rounds of coding with coder one were above the 80% agreement for interrater reliability.

Coder two, coder three and the researcher coded and discussed the mixed grade set of drawings first. After comparison of codes, the three coders were in agreement 85% of the time. The coders discussed the criteria and reviewed descriptors. One coder was coding **teacher attribute: working with the whole class**, "Teacher is depicted alongside or addressing a large group of students (more than 5 kids per group)" which is not possible to determine when no students are depicted. This resulted in some discrepancy. The external coders and research reviewed a drawing where the teacher was drawn at the board, and there were speech bubbles, indicating someone was responding but without seeing students depicted there was variation in how this teacher working with criteria was coded. Based upon the codebook it is defined by students being depicted. There were drawings where residue from students erasing something were visible, so a partial but clearly tried to erase piece was in the drawing. As this was not addressed in the codebook, the decision was that it would not be included in the coding. In-between sets, coder two asked about number corner and workplaces because some students had labeled those in the drawing and coder two was unfamiliar them. The researcher clarified that number corner is part of a math program where the class engages in number strings, counting collections, and other number sense routines, while workplaces are games that are used within that math programs lessons. The second set resulted in 85% agreement among all three coders and the final set resulted in 89% agreement. Again, agreement of the three coders was above 80% and therefore met the established criteria for interrater reliability.

Limits and Delimitations of the Study

Integrating the qualitative and quantitative data sets provided a deeper understanding (Leavy, 2017) of learner's experiences in math class. Narrowing the focus in this study to elementary students allowed a population that is not always asked about their experiences to have a voice in the research world (Leyva et al., 2021). Insider status, from working within multiple districts and elementary schools, provided the researcher with beneficial knowledge of elementary school classrooms. Background knowledge of math programs and instructional practices made components like pocket charts, number paths, and number corner elements recognizable and easier to code.

Using a codebook and establishing interrater reliability with additional coders helped to ensure consistent interpretation of the drawings. This tool was already researched for validity and reliability. Established defined criteria from a codebook supported reliable coding. Intentionally selecting drawings with words helped to reduce misinterpretation of drawings in the qualitative analysis.

As this study used existing data, there was not the opportunity to engage with students, or teachers, to learn more about their perspective, feelings and thinking with interviews or by asking for clarification about their drawings. However, due to the drawing tool and codebook having been researched, with some studies that included interviews for validation, it eased concern and provided a way to characterize the data with that valid and reliable tool. A few drawings were very difficult to identify many aspects from the codebook, or had undiscernible images contained within them.

Another limit is that the researcher did not administer the drawing task. Therefore, there is unknown variability in the messaging and directions provided by teachers or other adults who administered the drawing task. Furthermore, follow up prompts, guidance, or directions to individual students that may or may not have happened is not known. Differences in prompts, messages, or guidance as well as relationships with whoever was administering the tool could impact how learners portrayed their experiences.

The teacher survey data represents responses from 123 educators across elementary and middle school, and there is not a way to identify those teachers in sixth grade and up. This could influence the data. Most of the educators are elementary teachers, so the majority of responses come from K-5.

Another limit of this study is that this sample, nor a single drawing, might not fully represent the variety of feelings, experiences, and beliefs about learning math at schools in other states and locations. There is a lack of individual information, no demographics of students are available so no knowledge of which experiences are depicted from those in historically marginalized groups Due to this, future research in the experiences of students in different settings across the country would be beneficial to capture more narratives and perspectives. This could be done with full knowledge of students, their identities, and demographics, so more insight as to their experiences and how they connect to the literature could be analyzed. As would studies including PK-12 grade learners where younger and older experiences to be considered over time. While this research is not generalizable, it is an opportunity to better understand and share student experiences of what learning mathematics looks like in an elementary classroom. This research could be repeated in other areas for additional information and to strengthen understanding of the phenomenon of learning math.

CHAPTER FOUR: Results and Analysis of Data

An analysis of the overall numbers of each attribute in the drawings gave a nuanced picture of the various classroom experiences. A quantitative coded approach from 348 student survey drawings was used for a comparative statistical analysis, and a qualitative observation method of categorizing attributes of interest related to emotions in the classroom was used to compile a case study of drawings for deeper analysis. Results from teacher surveys were used for triangulation of the data for both the quantitative and qualitative analysis. Results were considered in relation to each research question. For each question, data has been presented, analyzed, and summarized to highlight results within that data set that are relevant to the research question.

While the codebook provided the structure to quantify the drawings, for this analysis the codes were rearranged to be more in sync and parallel to the four areas of exploration to connect features and ideas to the elements of *mathematical identity formation* and *equitable instruction*: 1. environment (furniture, classroom decorations and features), 2. mathematics (type of mathematics, visuals, math tools and technology), 3. interactions (communication, working individually/small/large group, teacher location) and 4. emotions (student emotions, teacher emotions).

This data was part of the Brocksburg School District (BSD) mathematics review. Redacted student drawings and teacher survey results were obtained for this review. The sample of student drawings ranged from kindergarten to fifth grade and attended one of three elementary schools in the BSD (n = 348, see Table 1). Most drawings were from kindergarten (32%) and grade three (24%). There were 123 teachers of PK to grade 8 who responded to the teacher survey.

Table 1

Number of Drawings by Grade Level

Grade	K	1	2	3	5	5	Total
Number of Drawings	112	28	45	83	48	32	348

Collectively, the drawings capture snapshots of the community experiences for students in BSD, experiences vary from class to class and learner to learner yet showcase a quantitative look at the patterns and perceptions. Individually the observation of the nuances of the drawings provided a snapshot of a more individual learner experience. Here, we will be looking at the ways students perceive and express their experiences in the math classroom, and then the similarities and differences in early elementary (K-2) in comparison with upper elementary (3-5) as portrayed by the learners (research question 1 and 2). By merging the K-2 and the 3-5 grade level data, a weighted Chi-square test was used to not statistical differences in features in drawings. For all tests a level of risk .05 level of significance was used.

Environment

In considering environment, the data focused on furniture and décor featured in the drawings. The details and scope of the environment varied from drawing-to-drawing. There were drawings that appeared like a map of the classroom, others that showed a single desk with a single student and nothing else in the environment, and others that captured the components of a math class.

In all the classroom environment coding, the most significant difference was seen in upper lower elementary differences was in the absence/presence of **Whiteboard/ Smartboards** *(p-value<.001)* and **kidney shaped** *(p-value< .001)* tables in drawings (see Table 2). The upper elementary grades had more of both of these features included in the drawings as compared to the lower elementary grades, as seen in Figure 5. Other codes to note here for future consideration and researcher reflection are desk arrangement, nontraditional furniture, and classroom decorations.

In looking at the furniture of the classroom, there were two codes for arrangement of student desks. There were many drawings with **desks clustered**, or tables with multiple students or multiple chairs at the same table, first and fifth grade had the highest percentage depicted, seen in Table 2. Second and third grade were the only grades where the drawings depicted a higher percentage of **desks in rows/grids** (not touching), as depicted in Table 2.

Nontraditional furniture was depicted in a low number of drawings (n=7), creating a more inclusive and flexibility space for seating and discussion options for students in the classroom. For example, instead of chairs at tables there were exercise balls being used by some students, or in another drawing a student was working on a couch in the classroom. Additionally, there were multiple fourth-grade drawings that depicted student standing desks offering another option for students to work in different places than only in chairs/desks.

Classroom decorations (n=45) were not all specific to mathematics, they sometimes provided a sense of hominess to the drawings that had a lot of decor details. Some of the details included insights into math - the number line hanging near the ceiling with place value markers, the posters with multiple strategies, and encouraging phrases students see in their environment grant views as to subtle messages the environment surrounds them with. These nonverbal messages may be interpreted and internalized from the classroom environment.

Table 2

Classroom Environment Features by Grade Level

*The total drawings for each grade with that characteristic, as well as the percentage of that grade levels drawings with each characteristic are shown. The highest percentages are bolded for features that have been discussed more. There was a significant difference in the absence or presence of Whiteboard/Smartboards (p<.001), kidney shaped tables (p<.001) in drawings from K-2 compared with grades 3-5. The upper elementary grades had more of these features included in the drawings as compared to the early elementary grades (** p<.001 and * p < 05).*

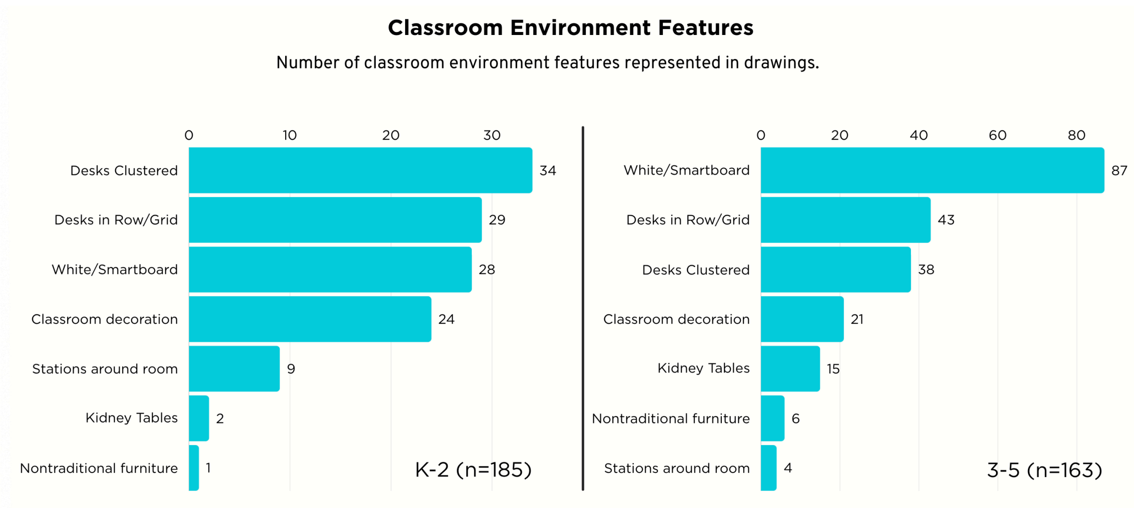
Classroom Environment Features

Grade (N = Total) Percent (n = Count of attribute)	**K** N = 112	**1** N= 28	**2** N = 45	**3** N = 83	**4** N = 48	**5** N = 32
Student desk clustered	14% (n=16)	**32%** (n=9)	20% (n=9)	12% (n=10)	25% (n=12)	**50%** (n=16)
Student desk in rows/grid	13% (n=10)	21% (n=6)	**29%** (n=13)	**39%** (n=32)	19% (n=9)	6% (n=2)
Station/Centers around room	3% (n=3)	14% (n=4)	4% (n=2)	2% (n=2)	4% (n=2)	0% (n=0)
Whiteboard/Smartboard **	9% (n=10)	18% (n=5)	29% (n=13)	**39%** (n=32)	**58%** (n=28)	**84%** (n=27)
Kidney Shaped Tables **	0% (n=0)	0% (n=0)	4% (n=2)	4% (n=3)	17% (n=8)	13% (n=4)
Nontraditional Furniture	0% (n=0)	4% (n=1)	0% (n=0)	4% (n=3)	2% (n=1)	6% (n=2)
Classroom Decoration	5% (n=16)	14% (n=4)	9% (n=4)	16% (n=13)	8% (n=4)	13% (n=4)

Figure 5

Classroom Environment Features by Grade Span

This graph shows the total number of drawings with each classroom environment feature depicted for grades K-2 and grades 3-5. Features are shown in decreasing order of frequency.



Mathematics

The analysis of the mathematics in the drawings for this study considers elements of how learners are showing conceptual understanding and meaning making through engaging with problems, tasks, and peers. Quantitative data about the math topic and codes that represent visuals, math tools, and technology, that captured how learners were engaging with the mathematics were included in this section. There were no statistics run on the topics, tools, or visuals, as this data was only used to observe trends and frequency of representation in drawings for future research ideas.

It was very interesting to note that the type of mathematics in the standards is represented in the general distribution of topics in student drawings, for example, Kindergarten to second grade drawings had addition and subtraction and did not have any multiplication or division represented, as shown in Table 3, those topics are beyond the scope of curriculum for those grade levels (Common Core State Standards, 2010). The K-2 drawings primarily represented counting/number line and addition while multiplication, addition and division were most common in the 3-5 drawings with discernable mathematics.

Also, fractions and decimals are only formally taught with fractions written as numbers beginning in grade three, visuals and fractions named with words are included from kindergarten (Common Core State Standards, 2010). These were represented in very few drawings.

Some drawings had no mathematics evident and therefore were not coded for type of mathematics. The category **can't discern math** was defined in the codebook as "some form of math is depicted not discernable in another category", this was a code used often with games as some math was happening, but it was not evident as to which other category it might, or might not, fit into, as seen in Table 3.

Table 3

Type of Math by Grade Level

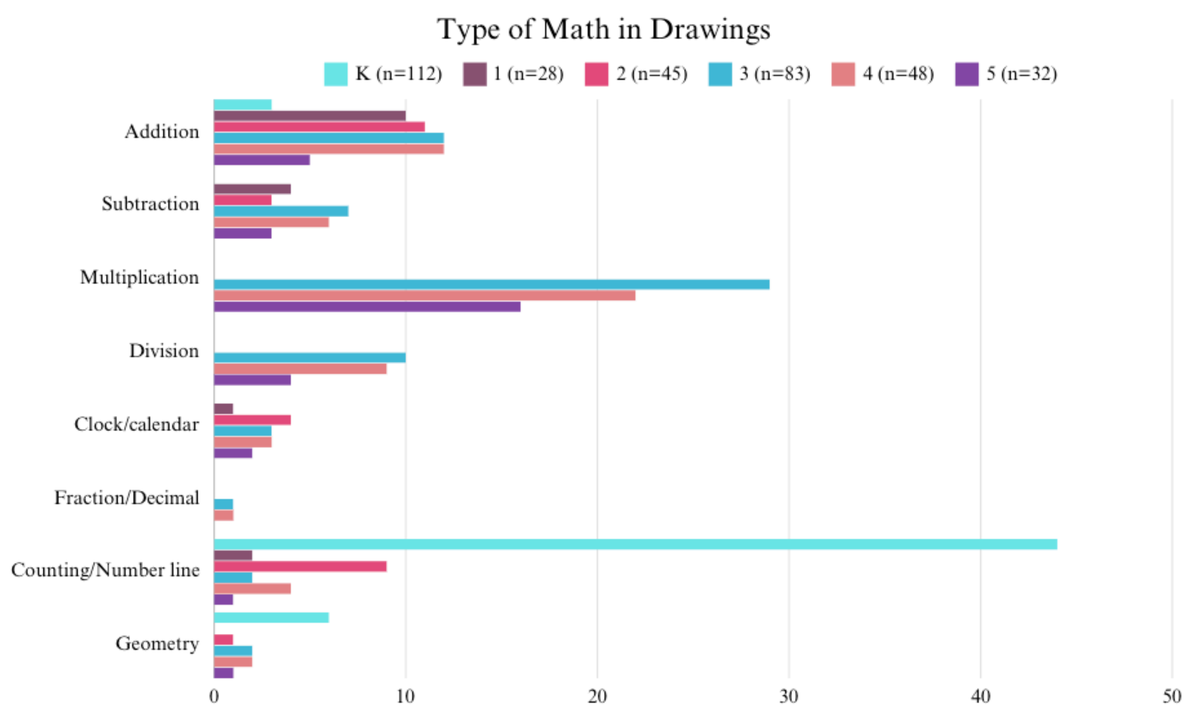
For each topic the total and percentage of each grade level drawings are shown. Some drawings had more than one type of math depicted.

Type of Math Depicted						
Grade (N = Total) Percent (n = Count of attribute)	**K** n = 112	**1** n = 28	**2** n = 45	**3** n = 83	**4** n = 48	**5** n = 32
Addition	3% (n=3)	**36%** (n=28)	**24%** (n=11)	14% (n=12)	**25%** (n=12)	16% (n=5)
Subtraction	0% (n=0)	**14%** (n=4)	7% (n=3)	8% (n=7)	**13%** (n=6)	9% (n=3)
Multiplication	0% (n=0)	0% (n=0)	0% (n=0)	35% (n=29)	46% (n=22)	50% (n=16)
Division	0% (n=0)	0% (n=0)	0% (n=0)	12% (n=10)	19% (n=9)	13% (n=4)
Clocks/Calendar	0% (n=0)	4% (n=1)	9% (n=4)	4% (n=3)	6% (n=3)	6% (n=2)
Fractions/Decimals	0% (n=0)	0% (n=0)	0% (n=0)	1% (n=1)	2% (n=1)	0% (n=0)
Counting/number line	**39%** (n=44)	7% (n=2)	**20%** (n=9)	2% (n=2)	8% (n=4)	3% (n=1)
Geometry	5% (n=6)	0% (n=0)	2% (n=1)	2% (n=2)	4% (n=2)	3% (n=1)
Can't discern Math	25% (n=28)	25% (n=7)	42% (n=19)	16% (n=13)	8% (n=4)	21% (n=7)

Figure 6

Type of Math Depicted in Each Grade Level

This graph shows how many drawings contained a depiction of each type of mathematics. Some drawings show multiple types of math, and others are not on this graph as they did not show any mathematics or any discernable type of mathematics.



In addition to content, the math tools and technology provide information about access to mathematics. Math tools and technology did not have consistent trends across the grade span, as shown in Table 4. While presence of equations was not coded, most of the types of mathematics were determined through equations in drawings. As evidenced by the infrequent manipulatives/hands on math tools and visuals, shown in Table 4 and 5, much of the mathematics was depicted through abstract models rather than concrete or representational models.

Table 4

Math Tools and Technology by Grade Level

The total drawings for each grade with that characteristic, as well as the percentage of that grade levels drawings with each characteristic are shown. The highest percentages are bolded for features that have been discussed more.

Math Tools and Technology						
Grade (N = Total) Percent (n = Count of attribute)	**K** n = 112	**1** n = 28	**2** n = 45	**3** n = 83	**4** n = 48	**5** n = 32
Book/Paper/Pencil	8% (n=9)	**36%** (n=10)	27% (n=12)	**43%** (n=36)	23% (n=11)	**34%** (n=11)
Manipulatives/hands on math tools	**21%** (n=23)	4% (n=1)	**16%** (n=7)	1% (n=1)	0% (n=0)	0% (n=0)
Games	**17%** (n=19)	4% (n=1)	11% (n=5)	7% (n=6)	2% (n=1)	6% (n=2)
Computer/Technology for:						
Students	0.9% (n=1)	14% (n=4)	16% (n=7)	17% (n=14)	2% (n=1)	9% (n=3)
Teachers	0.9% (n=1)	0% (n=0)	4% (n=2)	2% (n=2)	2% (n=1)	**19%** (n=6)
Other	0% (n=0)	4% (n=1)	0% (n=0)	4% (n=3)	4% (n=2)	0% (n=0)

Visuals were limited in all drawings, as seen in Table 5. Place value was not a specific category within the codebook, for math type it was coded under **can't discern** based on the descriptor "Some form of math is depicted not discernable in another category." However, to represent the drawings, (n=8) that did include place value representation in words or visuals they were included in Table 5. The highest prevalence of place value in grade two is consistent with the primary focus on understanding place value and relating place value to additive strategies in the standards, however, it is still a small subset of the grade level drawing set. Visuals and modeling are explicit within the standards for the operations that were commonly shown, namely addition and multiplication, (Common Core State Standards, 2010) yet visuals and modeling are limited in student drawings.

Table 5

Math Visuals by Grade Level

The total drawings for each grade with visuals characteristics, as well as the percentage of that grade levels drawings with each characteristic are shown.

Math Visuals						
Grade (N = Total) Percent (n = Count of attribute)	**K** n = 112	**1** n = 28	**2** n = 45	**3** n = 83	**4** n = 48	**5** n = 32
Arrays/ Visual Array	3% (n=3)	4% (n=1)	9% (n=4)	6% (n=5)	4% (n=2)	0% (n=0)
Dot Cards	0.9% (n=1)	4% (n=1)	2% (n=1)	0% (n=0)	0% (n=0)	0% (n=0)
Place Value Words and Visuals	0% (n=0)	0% (n=0)	15% (n=7)	0% (n=0)	0% (n=0)	0% (n=1)

Classroom Interactions

Classroom interactions focused on communication, how students were working, who teachers were working with, and where teachers were working within the classroom. Across all grade levels working individually was depicted more frequently than working in small or large groups. Communication and interactions were low across each grade level, as seen in Table 6.

Despite this low prevalence, when examining the drawings themselves there were some that implied communication despite students not being present. One drawing had a teacher at the front of the room and speech bubbles but no students in the scene, in adherence to the codebook this was not coded as student/teacher communication as no students were depicted. Examination of the details of the drawing through qualitative observations in this case is important to enhance understanding learner's perspectives by incorporating information that exists beyond the definitions of the codebook and quantified data (to be discussed further after the quantitative data findings).

In considering the differences in where teachers are working within the classroom (in the front of the room/at the board, at the teacher desk or at the rug) statistical differences were evident between the K-2 and 3-5 experience (*p=.019*), as to where the teacher was present (see Table 6). Student communication also had a significant difference, where students in lower elementary were more likely to be talking with other students, and the upper elementary would be talking with teachers *(p=.049)*. This result is taken lightly because of the p value and the small sample size; however, it is something to look at further in the future.

Table 6

Classroom Interactions by Grade Level

For each interaction the total number and percentage of drawings at each grade level are shown. Some drawings had more than one type of interactions. The highest percentages are bolded for features that have been discussed further. There was significant difference in the communication of student with students or with teachers (p=.049), and teachers working at the board/front of room, on the rug or at teacher desks (p=.019) in drawings from K-2 compared with grades 3-5. (p <.05).*

Classroom Interactions by Grade

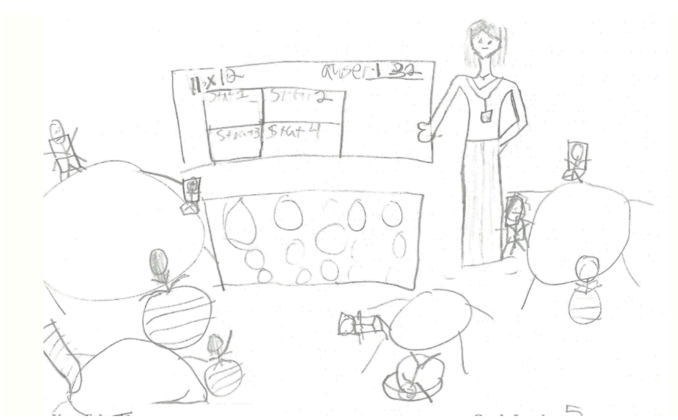
Grade (N = Total) / Percent (n = Count of attribute)	**K** n = 112	**1** n = 28	**2** n = 45	**3** n = 83	**4** n = 48	**5** n = 32
Students communicating with *						
Other students	4% (n=4)	**11%** (n=3)	7% (n=3)	5% (n=4)	4% (n=2)	3% (n=1)
Teachers	2% (n=2)	0% (n=0)	4% (n=2)	**10%** (n=8)	2% (n=1)	9% (n=3)
Students working						
individually	37% (n=41)	39% (n=11)	47% (n=21)	47% (n=39)	29% (n=14)	34% (n=11)
in small groups	**14%** (n=16)	**14%** (n=4)	**13%** (n=6)	**14%** (n=12)	6% (n=3)	**16%** (n=5)
in large group	9% (n=10)	**18%** (n=5)	11% (n=5)	**20%** (n=17)	8% (n=4)	**19%** (n=6)
Teacher working *						
at board/front of room	8% (n=9)	**18%** (n=5)	9% (n=4)	**27%** (n=22)	**17%** (n=8)	**28%** (n=9)
at teacher desk	0% (n=0)	0% (n=0)	7% (n=3)	5% (n=4)	2% (n=1)	3% (n=1)
depicted on the rug	2% (n=2)	**11%** (n=3)	2% (n=1)	1% (n=1)	0% (n=0)	0% (n=0)
Teacher working						
with individual student	0.9% (n=1)	4% (n=1)	4% (n=2)	2% (n=2)	2% (n=1)	9% (n=3)
with small group of students	2% (n=3)	4% (n=1)	4% (n=3)	4% (n=3)	2% (n=1)	9% (n=3)
with whole class	5% (n=6)	**14%** (n=4)	4% (n=2)	**22%** (n=18)	8% (n=4)	**22%** (n=7)

In looking more deeply at the data represented in upper elementary grades, of where the teachers spent more time at the board/front of the room, the use of qualitative data was used. The quantitative data does not provide details about the instruction happening, but the more qualitative observational information can be used to begin to gain more depth in the learner's classroom experience overall. In nine drawings, fourth graders (n=2) and fifth graders (n=7), there were representations of an equation and multiple strategies or boxes for multiple strategies, an example is shown in Figure 7. Some of these could have been from the same class and showing something that was in students' recent memory because a few of these drawings show the same exact multiplication problem. There were also two third-grade drawings where they showed strategy and vocabulary lists on the board. Only in upper elementary grades are there examples of multiple strategies or discussions about strategy in some classrooms.

Figure 7

Multiple Strategies Discussed in Math Class

This drawing depicts the teacher representing multiple strategies in the class.



A small subset of drawings represented the variability of activities and components to a math class. Eight learners captured the multiple experiences they have in math class. Six students (in third (n=4), second (n=1) and fifth (n=1) grade) sectioned off the paper and depicted different scenes, shown in Figure 8. While it is unclear if those scenes are components of the same day or portrayals of different days, they characterize the variety of math class. Most of these drawings came from third grade (n=4). Second and fifth grades each had one drawing that was done in this way. Similarly, two third graders depicted three or four sections and numbered them, showing a sequence of what they experienced during math time, in Figure 9. This demonstrates a variety of interactions including independent, small, and large group instructional opportunities. While these interactions are depicted without dialogue, there is implied communication from students playing games together or interacting with a teacher or peer.

Figure 8

Sample of drawings where students sectioned off the paper and showed multiple scenes.

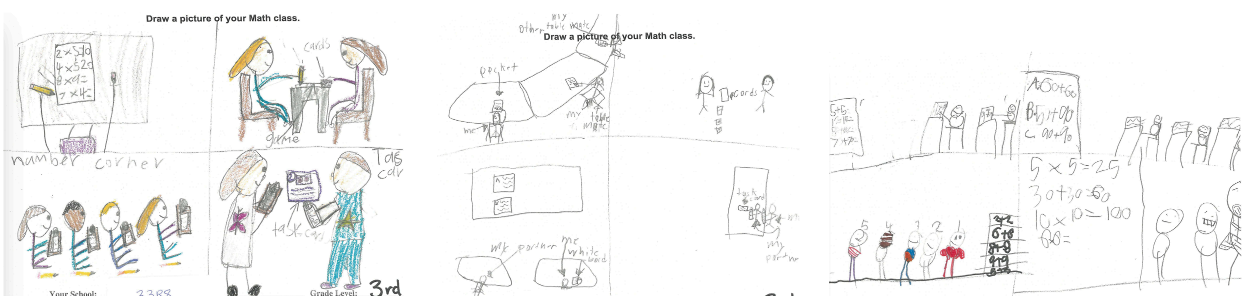
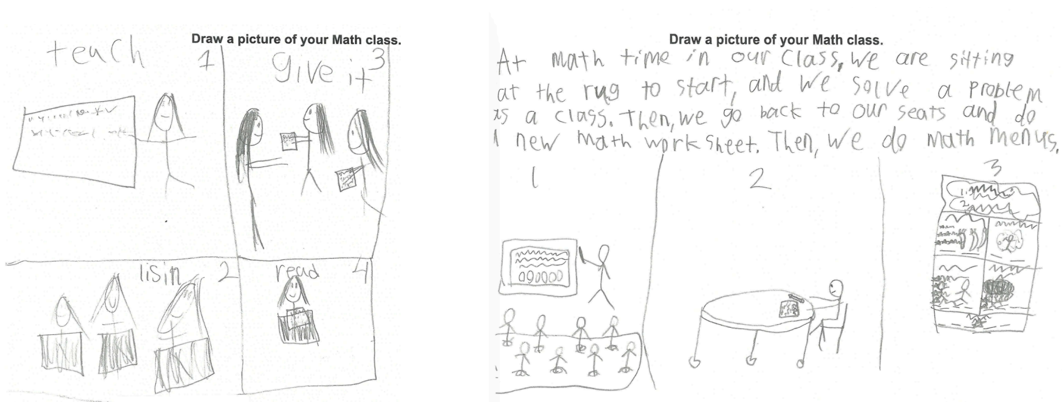


Figure 9

Drawings where students depicted the sequence of events in math class.



Emotions

Emotions were coded for all students depicted in drawings as well as all teachers in the drawings. Some drawings had multiple people with different emotions therefore those drawings are counted in multiple categories. In some images, many students with the same emotions were depicted, while in others there was a range of emotions for different students. Furthermore, a large portion of drawings with either students or teachers depicted did not have discernable emotions. In some instances that was because people were seen from the back, in other cases no facial features were included on the drawings.

For drawings where students were depicted, there was a high percentage of drawings with students showing positive emotion in second grade (73%). Aside from second grade, there was a slight decrease over time in the percentage of drawings with students depicted positively until third grade then there is a steep drop with much fewer positive emotions in fourth and fifth grade, as shown in Table 7. Students depicted negatively peaked in third and fourth grade, as seen in Table 7. This pattern of decreasing positive student emotions and more negative emotions is echoed in the written words expressing emotions there was a mix of positive and negative words in 3rd grade and only negative words written in 4th and 5th grades. When emotions (positive, negative, or neutral) of students depicted in drawings from early and upper elementary were compared, there was a significant difference between K-2 and 3-5 *(p=.001)*.

Table 7

Student Emotions by Grade Level

The number of drawings that had each emotion depicted, as well as the percentage of all drawings in that grade level with that emotion depicted on students, and the percentage of drawings with an emotion depicted out of only the drawings with one or more students depicted. There was a significant difference (p=.001) in expression of positive, neutral, or negative emotions portrayed on students in the drawings from grade K-2 compared with 3-5. (p<.01)*

Student Emotions in Math Class

Student(s) depicted		K N = 112 n = 72	1 N = 28 n = 19	2 N = 45 n = 30	3 N = 83 n = 64	4 N = 48 n = 23	5 N = 32 n = 18
Positively *	Count	42	10	22	30	6	3
	Percent of all drawings	38	36	48	36	13	9
	Percent drawings with students depicted	**58**	**53**	**73**	47	26	17
Negatively *	Count	9	1	2	13	5	0
	Percent of all drawings	8	4	4	16	10	0
	Percent drawings with students depicted	13	5	7	**20**	**22**	0
Neutral *	Count	11	4	4	20	7	4
	Percent of all drawings	10	14	9	24	15	13
	Percent drawings with students depicted	15	21	13	31	**87**	22
Can't Discern Emotion	Count	32	11	11	32	11	15
	Percent of all drawings	29	39	24	39	23	47
	Percent drawings with students depicted	44	58	37	50	48	**83**

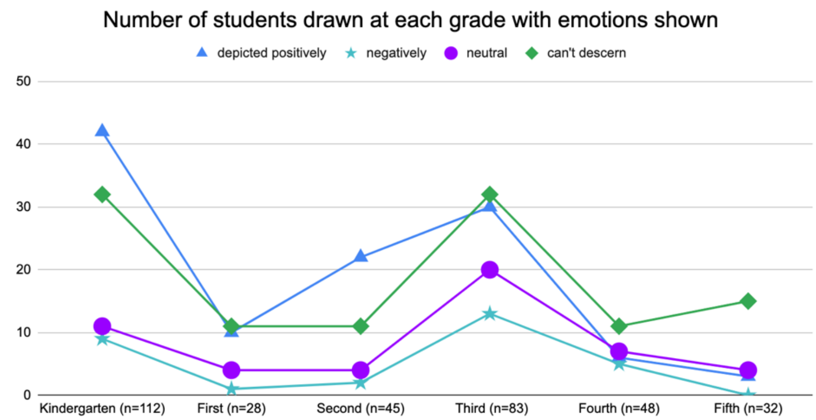
N = all drawings for grade level /n = drawings with students depicted in that grade level

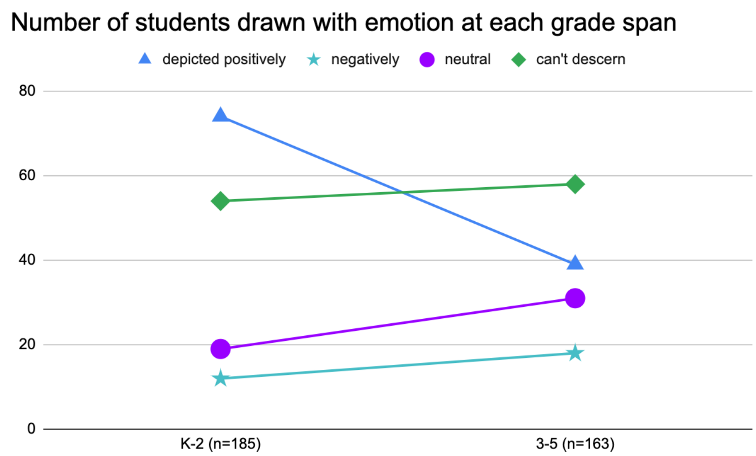
While positive emotions declined, negative emotions do follow a general increase from K-2 compared to 3-5, see Figure 10. Again, when looking at grade level numbers there is more to the story, and it is not as linear. Kindergarten and fifth grade do not follow the pattern, with kindergarten having a higher percentage of negative drawings (13%) compared to other early elementary grades and fifth grade having no negative student emotions depicted in facial expressions of students in drawings.

Figure 10

Student Emotions in Drawings

The top graph shows the frequency of student emotions depicted in drawings by grade level. The bottom graph shows the number of students emotions depicted by each grade span.

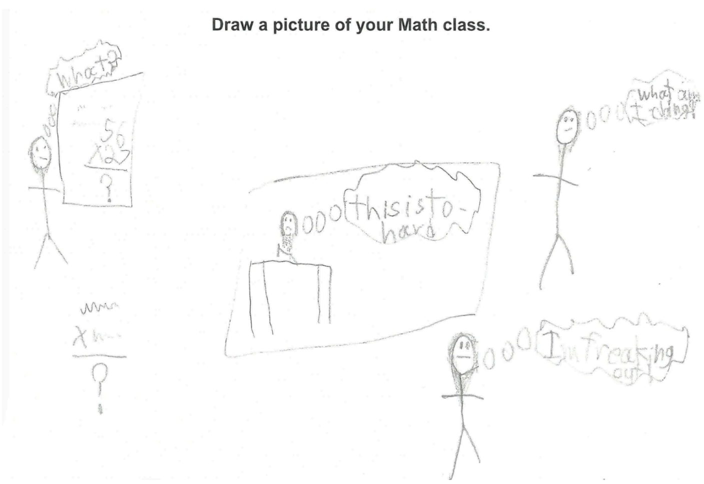




Looking at the details of the drawings alongside the counts of attributes exposes aspects that are not represented by quantitative analysis alone. Another example of this is speech and thought bubbles in the qualitative observations. Although thought bubbles were not coded, those reveal, at least in part, what students are thinking. Some were question marks – maybe representing unknown answers or a way to show thinking. Student thoughts also captured in reviewing thought bubbles, provide more insight around student emotions, for example, sketches of sheep and “zzzzz” in the thought bubbles or phrases like “I’m tired.” Drawings provided an opportunity for learners to express these emotions, and multiple feelings and thoughts they might have during math class, including “What?”, “This is too hard”, “I’m freaking out!” and “What am I doing”, see Figure 11. The complexity of student thoughts and emotions were evident in the drawings, as were the range of emotions and variety of thoughts that learners have about math class.

Figure 11

Sample drawing showing multiple emotions and thoughts a student has during math class.



In drawings where teachers were depicted, teachers are only shown with positive or undiscernible emotions in kindergarten through second grade, as shown in Table 8. Teachers were depicted negatively only in third and fifth grade and it was only in third, fourth, and fifth that teachers were depicted with neutral emotions. When emotions (positive, negative, or neutral) of teachers illustrated in drawings from early and upper elementary were compared, there was a significant difference between K-2 and 3-5 *(p=.010)*.

Table 8

Teacher Emotions Depicted in Drawings

The number of drawings that had each emotion depicted, as well as the percentage of all drawings in that grade level with that emotion depicted on teachers, and the percentage of drawings with an emotion depicted out of only the drawings with one or more teachers depicted. There was a significant difference (p=.010) in representations of positive, neutral, or negative emotions on teachers in the drawings from grade K-2 compared with 3-5. (p<.05)*

Teacher Emotions in Math Class

		K	**1**	**2**	**3**	**4**	**5**
	(N = all drawings for grade)	N = 112	N = 28	N = 45	N = 83	N = 48	N = 32
	(n = drawings with teachers depicted)	n = 15	n = 7	n = 11	n = 32	n = 11	n = 14
Positively *	Count	8	2	8	16	2	5
	Percent of all drawings	7	7	18	19	4	16
	Percent drawings with teachers depicted	53	29	**72**	50	18	36
Negatively *	Count	0	0	0	2	0	1
	Percent of all drawings	0	0	0	2	0	3
	Percent drawings with teachers depicted	0	0	0	**6**	0	**7**
Neutral *	Count	0	0	0	4	4	3
	Percent of all drawings	0	0	0	5	8	9
	Percent drawings with teachers depicted	0	0	0	**13**	**36**	**21**
Can't Discern Emotion	Count	7	4	6	9	5	5
	Percent of all drawings	6	14	28	11	10	16
	Percent drawings with teachers depicted	47	57	55	28	45	36

Based upon the criteria established and explained in chapter three, eight drawings were selected to provide individual experiences based upon words contributing to the depiction of student emotions and feelings about mathematics or math class. The details for the environment, mathematics, interactions, and emotions are represented in Table 9, an overview of researcher memos were provided here, with more descriptions in Appendix G.

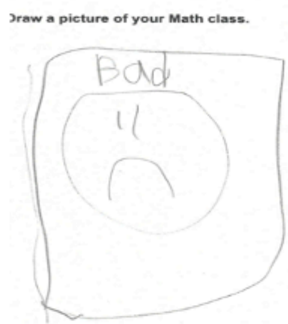
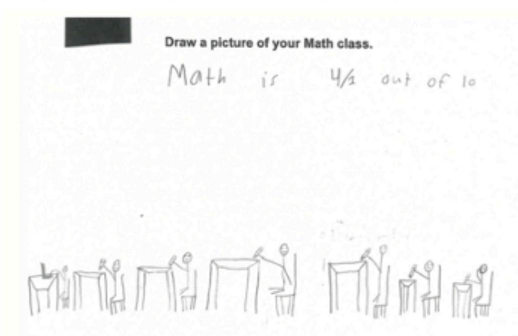
All but one of the drawings depicting positive emotions in words showed students sitting together at tables. None of the drawings with positive words depicted students with facial expressions. All the drawings with negative emotions, except Matilda's, showed a single student alone in the drawing. Matilda's was the only drawing in this set depicting negative emotion words with multiple students, the students were sitting alone in a row of desks, all with neutral or negative expressions on their faces. Teddy provided the most details in writing about why they liked math. These nine cases provided a deeper understanding of student emotions and reasons related to their feelings and attitudes about mathematics.

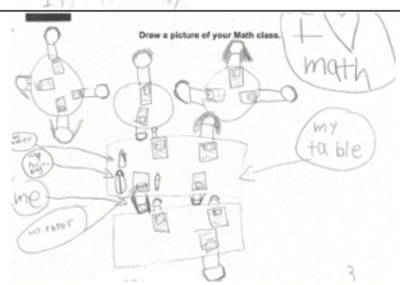
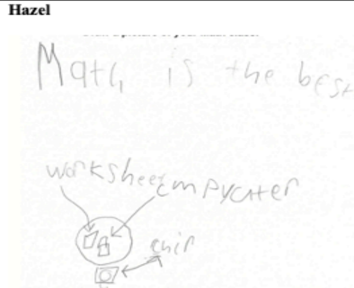
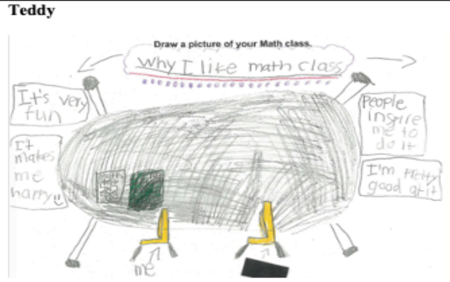
Throughout all categories of analysis, it was evident that the math class experience is not the same for any one student and the portrayal of experiences of students in the same class and district are unique and individualized. Overall, the learners' experiences suggest math class is a time to work individually most of the time. Equations and calculations are the most drawn math problems, most of which are addition and multiplication. As calculation was most prevalent in the form of equations, there were very few visuals or hands on manipulatives. Although there are not explanations for all the feelings, the trend was a decline in positive student emotions depicted as grade level increased. Mixed methods analysis provided an overview of all student's experiences in the BSD, not all learners are represented and as was clear from the drawings, every learner does not have the exact same experience in math class.

Table 9

Qualitative Analysis of Drawings with Words

These eight drawings were selected based on established criteria to highlight student experiences which included written words that went beyond labeling objects to provide information on emotions and/or experiences in the classroom. These drawings are all from third grade students.

Student Name and Drawing	Environment	Mathematics	Interactions	Emotions
Todd 	**Codes:** None **Description:** No details on the environment	**Codes:** **Description:** No math shown	**Codes:** One student depicted individually **Description:** Student depicted alone	**Codes:** Negatively **Description:** Sad – frown face "Bad" written above the face
Jason 	**Codes:** None **Description:** No details on the environment	**Codes:** Can't discern, Book/Paper/Pencil **Description:** Scribbles on worksheet cannot ready anything except name and date	**Codes:** One student depicted individually, Working individually **Description:** Student depicted alone next to worksheet	**Codes:** Positively **Description:** Happy face "Lame" written in speech bubble
Matilda 	**Codes:** Student desk in row/grid **Description:** Row of individual desks	**Codes:** Fraction/decimals, Computer technology for student, Book/Paper/Pencil **Description:** Scribbles on worksheet cannot ready anything except name and date	**Codes:** Multiple students, Working individually **Description:** Students all sitting alone at desks, most have paper/pencil one has a computer	**Codes:** Negatively, Neutral **Description:** Mix of students with frowning faces, or neutral expressions "Math is 4/1 out of 10" is written above the row of students

Sam 	**Codes:** Student desk in row/grid **Description:** Single desk with pattern depicted on floor There is a worksheet on the desk	**Codes:** Multiplication Book/Paper/Pencil **Description:** Single digit multiplication problem is written on the paper	**Codes:** One student depicted individually, Working individually **Description:** Student alone working at desk	**Codes:** Negatively **Description:** Student has frowning face, speech bubble says "So hard!" There are words surrounding the student on the page "Satisfying? Hard! Frustrating! Fun?"
Victoria 	**Codes:** Student desk in row/grid **Description:** Single desk with worksheet on the desk	**Codes:** Multiplication, Division, Book/Paper/Pencil **Description:** 1 ÷ 1, 2 x 4 are written on the paper	**Codes:** One student depicted individually, Working individually **Description:** Student alone working at desk	**Codes:** Negatively **Description:** Student has frowning face, speech bubble says "EZ" The sentence "It's to easy" is written below the student
Frankie [redacted] 	**Codes:** Student desk clustered **Description:** Students working at tables, 2-4 students at each table	**Codes:** Addition, Subtraction, Book/Paper/Pencil **Description:** + and - are written on some papers	**Codes:** Multiple students, Working individually **Description:** Students are sitting at tables with others working on individual papers	**Codes:** Undiscernible **Description:** I love (heart) math is written in the right corner above the classroom scene
Hazel 	**Codes:** Student desk in row/grid **Description:** Desk and chair for one student	**Codes:** Computer technology for student, Book/Paper/Pencil **Description:** Worksheet and computer on the desk, labeled	**Codes:** One student depicted individually, Working individually **Description:** Back of student sitting at desk	**Codes:** Undiscernible **Description:** No expression visible on student "Math is the best" is written across the top of the paper
Teddy 	**Codes:** Student desk clustered **Description:** Table with two chairs, one is labeled "me"	**Codes:** Multiplication Book/Paper/Pencil **Description:** Paper on table says math test with multiplication problems	**Codes:** Multiple students, Working individually **Description:** Two seats at a table	**Codes:** Undiscernible **Description:** "Why I like math class" with an arrow pointing to the right and left off each side of that top banner pointing to reasons for liking math class were: "It's very fun", "It makes me happy =) ", "People inspire me to do it" and lastly "I'm pretty good at it"

Triangulation of Teacher Data

To gain a deeper understanding of learners' experience in math class and how that relates to the experiences of teachers (research question 3) triangulation of student data with teacher data was done. The elements of mathematics interactions and emotion categories were included here as they were included from both student and teacher populations within the district. In considering the vision teachers hold for mathematics and their own personal feelings about mathematics, the quantitative analysis provided awareness of what elements are aligned and what differs from student to teacher.

Mathematics

The teacher data showed the frequency of words and phrases used to answer the open-ended question, "What is math?". The words were categorized by those that were about actions, in Figure 12, and those that were more about concepts, as seen in Figure 13.

An area of alignment between students and teachers was in visuals and math manipulatives. Models/Concrete Representational Abstract (CRA) was only mentioned by 9 teachers (7%) and is in line with the low portrayal of visuals and manipulatives in the student drawings (Table 4 and 5), 7% and 9% of all drawings respectively.

Other topics or characteristics did not match between students and teachers. Many teachers identified math as understanding the world, but math as related to the understanding world was not clear in student drawings.

Counting was only named by three teachers, however in kindergarten there were 44 drawings with counting depicted. Operations were only noted by one teacher, but equations were depicted in many student drawings. While thinking and reasoning, named by 54 teachers, is not something that has a code for the student drawings, it could be represented in the student drawings that had "?" thought bubbles as well as the drawings which showed multiple strategies on the board for a problem, although those were minimally represented by learners. This demonstrates a difference between teachers' notions around what math is and the mathematics students expressed as reflected and drew their math class experiences.

Figure 12

Math Actions Identified by Teachers

Teachers were asked "What is math?", the responses that are related to math actions are shown in this figure. The frequency of responses with each action noted are displayed.

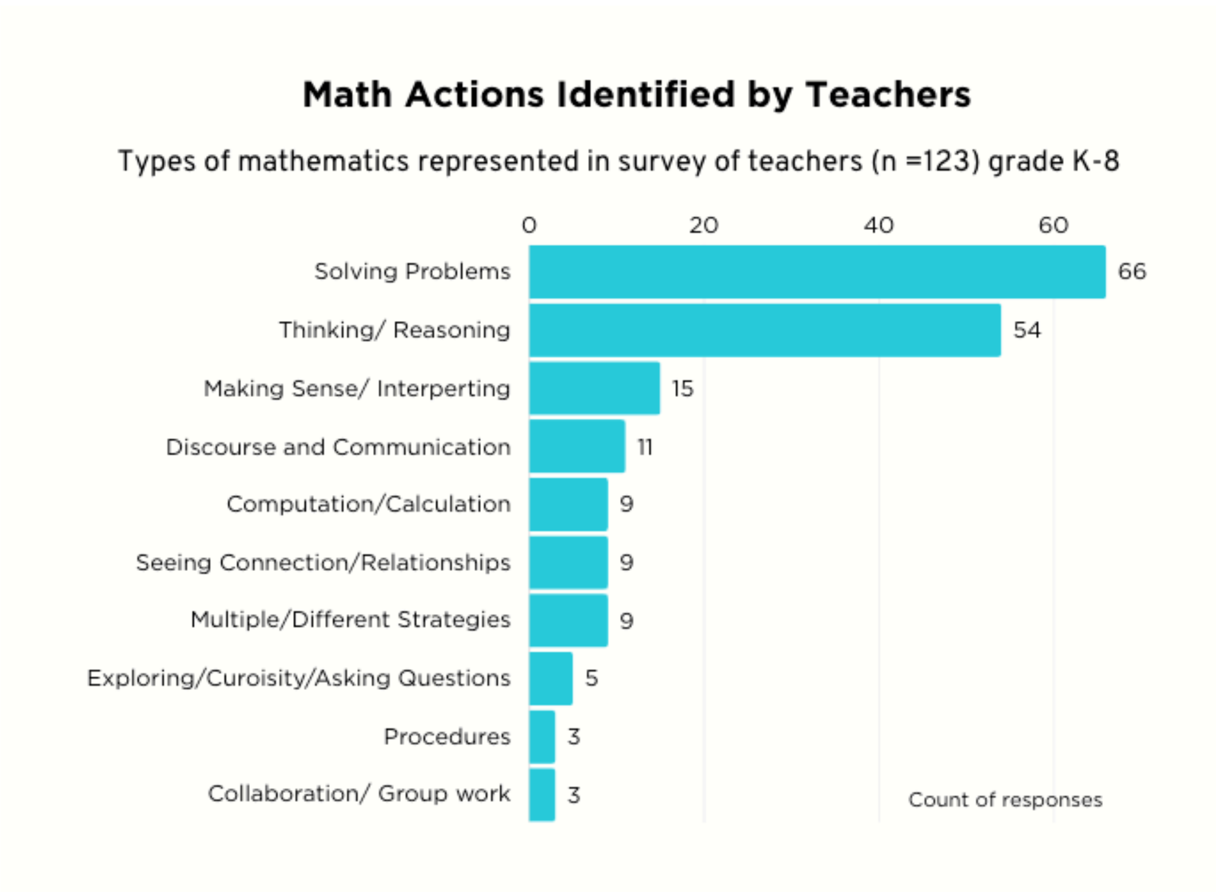
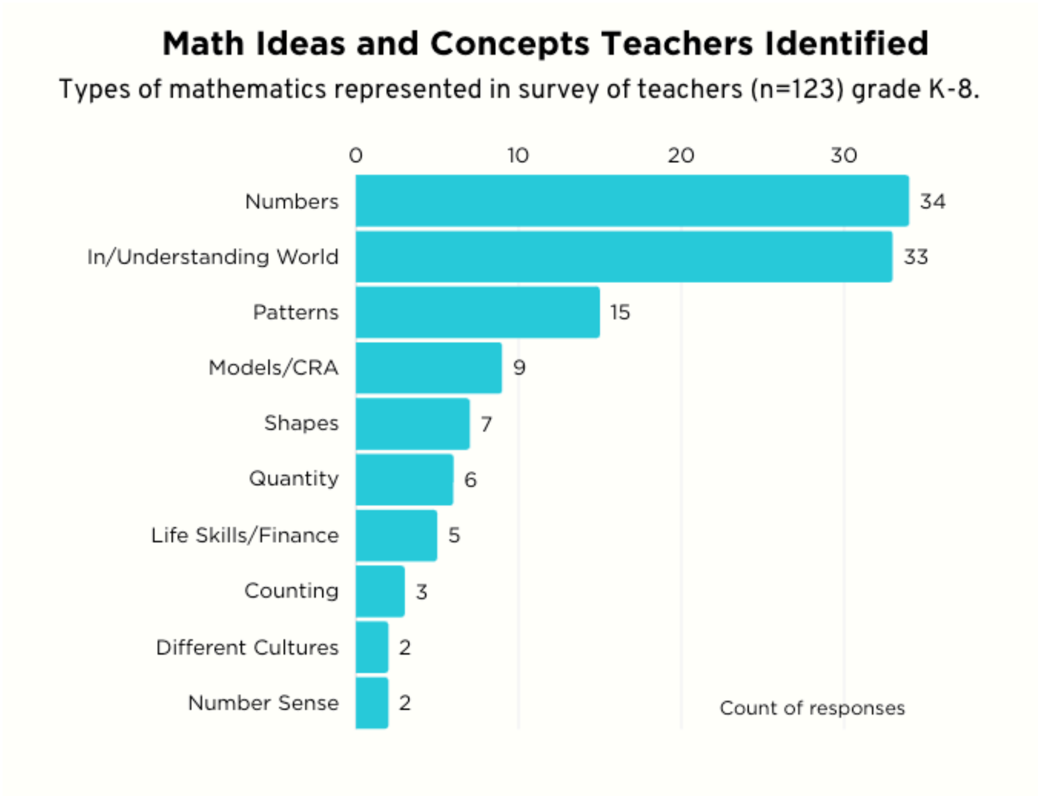


Figure 13

Math Ideas and Concepts Identified by Teachers

Teachers were asked "What is math?", the responses that are related to math ideas and concepts are shown in this figure. The graph shows the total number of responses with those words as a visual for their frequency.



Interactions

Few drawings showed student-to-student communication, which was in line with the low instance of collaboration named by teachers when they described what came to mind when they think about math. Collaboration/group work and discourse/communication were represented in a low percentage of teacher responses, 11%, as seen in Table 10. Student-to-student communication and teacher-to-student communication was depicted in 9% of student drawings, as seen in Table 10.

Table 10

Communication in Math Class

This table shows how many student drawings depicted communication between students and between teachers and students. Teachers who responded with group work/collaboration or discourse/communication as a response to "What is math" are included as they represent forms of communication.

Communication in Math Class			
Student Drawings n = 348		**Teacher Descriptions** n = 123	
Student to student communication	17	Group work/ collaboration	3
Student to teacher communication	16	Discourse/ Communication	11
Total Communication Represented	33		14
Percent of responses with Communication Represented	9%		11%

Emotions

Teachers could select one or more emotions on the survey, the results are shown in Figure 14. To align to the categories of the student drawing emotions the emotions on the survey were categorized in the following way: Positive (inspired, happy, interested); Negative (sorry, disgusted, bored, embarrassed, scared); Neutral (neutral); Can't discern (surprised). As the emotions were categorized by positive, negative, and neutral, surprised was categorized as "can't discern" because it could be positive or negative, and therefore based on survey results there was no way to establish how the teachers viewed the emotion of surprise. Then the data was compiled into the table shown in Table 11.

Analysis of teacher emotions represented was compared to the emotions students gave teachers in their drawings, see Table 11. There was a statistically significant difference in how students portrayed teacher emotions compared to how teachers portrayed their own emotions, *($p<.001$)*. There was also significance in the emotions (positive, negative, or neutral) as expressed by teachers when compared to the emotions represented on the students in the drawings *($p=.008$)*.

Figure 14

Math Emotions Identified by Teachers

Teachers were asked "How do you feel about math?", and selected emotions from the options. The graph shows the percentages of emotions as a visual for their frequency.

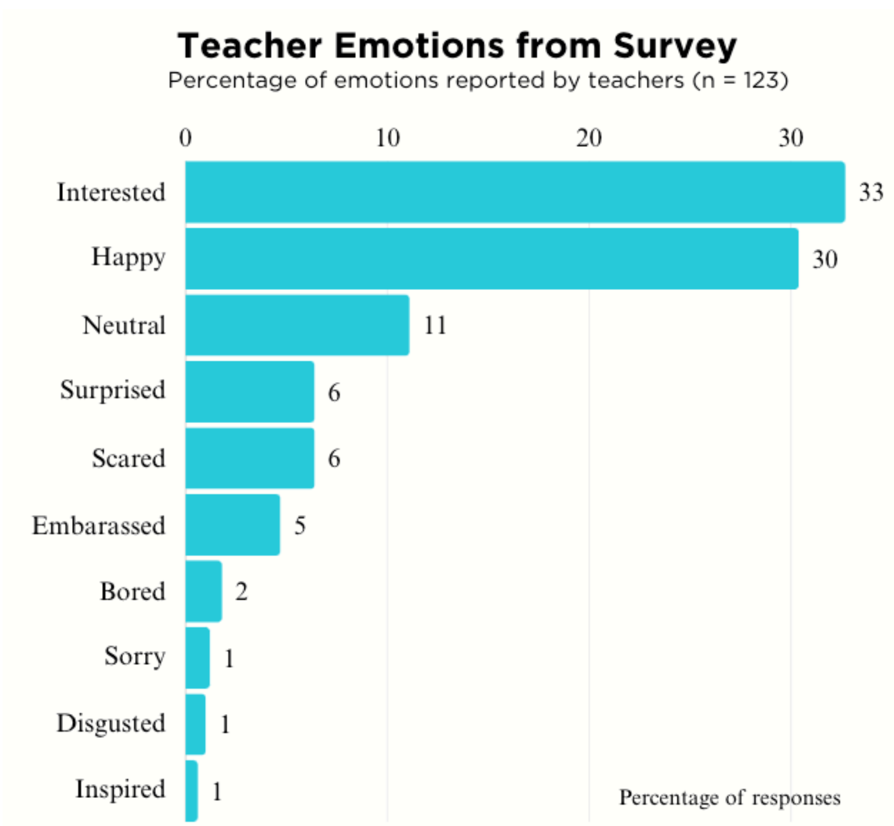


Table 11

Math Emotions of Students and Teachers

There was statistical significance in students showing teacher emotions compared to teacher expression of emotions (p<.001). There was also significance in the emotions expressed by teachers compared range of emotions represented on students in the drawings (p=.008). (p<.01, **p<.001)*

Student and Teacher Emotions

	Positive	Negative	Neutral	
Student Emotions represented in drawings by students N = 348/drawn with students n=226	113	30	50	*
Teacher Reported Emotions N = 123	108	24	19	
Teacher Emotions represented in drawings by students N = 348/ drawings with teachers n=90	41	3	11	**

Summary

Elementary school drawings provided learners perspectives on their math class experience. Drawings captured isolated moments as well as series of components of math block, showing not only single snapshots but also records of the variety and variation of math class. The qualitative stories provided details and insights into the nuances of classroom experiences. This was explored against the backdrop of the quantitative data that captures a range of experiences from the larger community of learners.

There were some significant differences between younger and older elementary student experiences in their classrooms. Where teachers work and expression of positive vs. negative student emotions were both statistically significant when considering K-2 compared to 3-5. Positive emotions are decreasing from early elementary to upper elementary, while negative emotions are increasing. The trend exists in the quantitative data from students represented in drawing and in the qualitative review of drawing with emotions written and described by the learners themselves. No positive words were documented in grades four or five, only negative words were included in drawings at those grade levels. In the qualitative review of drawings, the negative written emotions were combined with sad expressions, while the positive words did not show expressions on student faces. Some learners included single words on their feelings while others wrote more about their feelings or reasons they expressed an emotion about math class.

Overall, there are a mixture of characteristics identified by teachers that match the learner's representation of their math class experience, and others that do not match. Visuals, communication, and discourse are limited in representation and expression from both teachers and students. Expressing math as understanding the world, solving problems was more prominent for teachers, while calculations was more widely represented in drawings. There was a statically significant difference in teacher emotions as reported by teachers and as depicted by students, and between teacher reported emotions and student depicted student emotions.

CHAPTER FIVE: Summary and Implications

Research has often been done with a deficit focus rooted in what students don't know and finding ways to "fix" them (DeJarnette et al., 2020; Lambert, 2022.; Tan et al., 2019; Woodward & Tzur, 2017). As seen in the constructivist shifts in research, a strengths-based approach reframes thinking to consider the learner's strengths and existing knowledge and how they serve as a foundation to strengthen conceptual understanding and continued learning. A pluralist view of knowledge, and a strengths-based focus can support seeing differences not as deficits, but as simply a difference (Armstrong, 2010; Paris & Alim, 2017). These shifts also humanize learners by valuing them as well as their experiences and knowledge (Annamma & Winn, 2019; Boaler, 2016; del Carmen Salazar, 2013; Gay, 2002; Lambert, 2022; Roosevelt & Garrison, 2018).

The classroom environment is for students; therefore, it is crucial to understand, consider, and value their perspectives on their experiences when considering how to design instruction and spaces for their learning (Imm et al., 2024; Martin, 2000). Examining data about experiences, interactions, and emotions provides needed insight to explore mathematical identity formation and attitudes toward math which not only are important for seeing the value for math but impact learning as well (Hascher, 2010; Keown & Bourke, 2019). Learners' perspectives, especially those of younger students, are less prevalent in research as has been discussed. Analyzing data from elementary student drawings provided a way to humanize learners and gain more understanding of their experiences while providing younger learners' perspectives. Drawings reduce the power dynamics, as the expression is non-verbal, is not an adult-to-child conversation, and is a medium that children have skills and control over their communication. Therefore, this type of data addressed another key factor in critical pedagogies and social justice.

This study focused on student perspectives from existing student data, in the Brocksburgh School District, where learner-centered surveys were incorporated to show the student perspective and to address an audit recommendation. The district used research of Hanley et al. (2004), that began with a simple prompt from "Drawing on Math". Therefore Haney et al. (2004) and team established the existing codes, descriptions, and student drawing examples, and validated the comparison of what students were drawing with the actual classroom experience (via videos) the researchers also continued to validate the stability of coding of the drawings over time (Haney et al., 2004). The Brocksburgh School District also extended the use of surveys to better understand the perspectives of teachers around mathematics, inquiring on their feelings about mathematics, professional learning, and the district math vision and resources.

A mixed methods approach allowed insight into the math class experiences from the learner's perspective. Coding a large collection of drawings provided a rich source of quantitative data and provided the opportunity to observe trends of what students experience and see similarities and differences between early and later grades. Collectively, through quantitative analysis a group story can be told and patterns can be a strong way to look at drawings (Gamradt & Staples, 2023; Haney et al., 2004). These patterns and outliers in individual drawings deepen understanding of the quantitative data and the learners' stories. Contrasts and juxtapositions between teachers' views and students' depictions (Metcalfe, 2015) add context as to the teacher and systemic influences on the environment. Taking a deeper case-study approach in individual experiences, a subset of drawings was used for a qualitative review focused on learner emotions.

Summary of Findings

This study supports what other research has found in that drawings help teachers know more about their students and their feelings (Haney et al., 2004; Søndergaard & Reventlow, 2019; Weber et al., 2011). Having insight from all students, not just those who might be vocal about their feelings, is critical to developing strong relationships and in planning responsive teaching. Focusing on learners' perspectives and feelings about math is known to impact not only their math identity but their learning as well (Hascher, 2010), yet they do not always have as much attention as scores and content. Drawings provided rich information on learner's perspectives and experiences; their use has been validated in research as a reliable tool (Gamradt & Staples, 2023; Haney et al., 2004; Søndergaard & Reventlow, 2019).

Variation in the drawing styles and content highlight the individuality of learners. Using the same prompt, "Draw your math class", in diverse ways, learners shared experiences by depicting a series of events within their math class over the day or week, or used their artistic skills to capture details of their environments or were more focused on the people in the room. The prompt, though the same across all grades, was broad enough to allow learners to interpret and represent math class in whatever way they wanted to capture their experience, similarly the teacher survey was also open ended to allowing individual expression of "What is math?" for them. The qualitative analysis of drawings supported findings from the quantitative analysis, and although the sample size was intentionally low, these drawings provided rich descriptions and insight to support understanding of attributes in the drawings.

The data provided insight into the research questions and has been examined regarding access in two ways. First, to look at the accessibility of mathematical identity in relation to the data on messages shown in the environment, mathematics opportunities, interactions to elicit thinking, and emotions related to self and mathematics. Then to examine access to instruction using data from environmental features, mathematics concepts, tools, and visuals, interactions between students and teachers, and emotions portrayed considering how they all relate to deep learning.

Mathematical Identity

The data used in this study does not provide details on individual learner's identities, therefore the community makeup is the only context for consideration. The general student population is predominately white, a commonality shared with most peers and adults. This could impact learner's experience in ways that are not known from this study. There was no data that identified the understanding that educators have on the student population, culture, and background The impact of societal norms, culture, and values on instruction is recognized in research (Gonzalez, 2023; Gutiérrez, 2013; Leyva et al., 2021), and with a population that is mostly white these norms, values, and culture in schools could be more aligned to the community at large given the demographic makeup. Moreover, this data set does not reveal the impact of hidden curriculum (del Carmen Salazar, 2013; Gay, 2002) or the messaging or lack of representation in the curriculum (Boaler, 2016; Gonzalez, 2023; Martin, 2000) that could be the experience for the 20% of the learners.

Race is not the only feature of identity that could be impacted by the dominant cultural norms, messages, and curricular representations as potential barriers to access. Examination of student labels and services, such as Individual Education Plan (IEP), English Learner (EL), 504, and Educational Support Team (EST), might result in learners not having the same math experience as evidenced in the literature. IEP, EL, 504, and EST are different plans that document and define services and accommodations for students based on their learning needs, disability status, medical conditions, or if they are multilingual learners. Approximately 5% of the population is EL, 5% is on a 504, and another 4% is on an EST, and these labels have the potential to influence learners' access to positive math identities. Learners who are part of these demographic groups have stories captured within the larger data set but are not identifiable as to which experiences are being had by students who carry these labels. Labels can be deterministic of the access that they have to mathematical understanding and positive identity (Aguirre et al., 2013; Gonzalez, 2023; Gutiérrez, 2013; Lambert & Tan, 2020; Lei et al., 2020; Leyva et al., 2021; Tan et al., 2019). Bias, stereotypes, and perceptions are also held around class (Leyva et al., 2021). BSD has a population of approximately 20% of students on free and reduced lunch, one demographic indicator of class. Again, the perspectives of these learners are nested within the data but are not identifiable for consideration around this additional demographic and how it may impact learner's identity formation.

While messaging is not explicitly coded within the data, there are elements in some of the classroom decorations that suggest there may be environmental messaging around mathematics. As noted in the research, explicit or implicit messages can limit learners' views of themselves as mathematicians or allow them to recognize the value of productive struggle and see themselves as mathematicians (Boaler, 2016; Gonzalez, 2023; Keown & Bourke, 2019). Some students captured the environmental details including the posters and messages surrounding them in math class. For example, one poster said, "Math is fun."

There were student drawings that provided examples of classrooms with discourse. One drawing had students sharing incorrect answers and engaging in discourse with peers (shown in Appendix G). In this drawing there was discourse and it was evident that a strong relationship has been established between the students and teacher; a strong relationship is needed for student engagement (Ball, 2000; Kolb, 2015; Mehta & Fine, 2019) and vulnerability to share different answers than peers. Students would not be willing to share incorrect answers if a learning community had not been fostered. Discourse about strategies and answers could suggest a safe environment to share ideas. More questions come from examining this drawing: What do they do now? How do they explain and justify? Are they speaking and showing respect to their peers? But despite these questions, this still provides evidence that some students are experiencing a community of learning. Discourse in a classroom is one strategy to shift from teacher as providers of knowledge (Boylan, 2016).

Learning communities also provide messages about who belongs in mathematics. When aspects of math are not valued or student contributions are not valued and recognized it can be difficult for learners to develop positive mathematical identities (Hima et al., 2019). Eliciting student thinking and valuing their voice and knowledge can be an act to counter deficit narratives and norms (Garcia Olp et al, 2017) and assign competence to students (Boaler, 2016). Collaboration and discourse provide one way of recognizing student strengths, which humanizes learners and can provide them with opportunities to succeed, to resist stereotypes and labels (Aguirre et al., 2013; Martin, 2000; Paris & Alim, 2017).

Other drawings demonstrated examples where multiple strategies were represented (see Appendix G) exemplifying a classroom community of learners recognizing students as "mathematically competent" (Garcia Olp 2017) and promoting flexible thinking. In some drawings, multiple strategies were being sought and/or represented to solve a problem. There are more questions to be asked for the details of what was going on with this classroom conversation. However, this did show some instances where flexibility and multiple strategies may have been part of students' experiences in math class. Such a learning community values learners and is essential for deep learning (Allison & Pomeroy, 2000; Delaney & Mayer, 2021; Farnsworth et al., 2016; Ladson-Billings, 2017; Mehta & Fine, 2019), collaboration (Ball, 2000;

Darling-Hammond & Oakes, 2019; Kolb, 2015; Mehta & Fine, 2019) and problem-solving (Boaler, 2016; Huinker, 2020; National Council of Teachers of Mathematics, 2014a, 2014b, 2018, 2018) and would be expected to be represented frequently for classrooms focused on equitable and accessible instruction.

Drawings showed that there is variability in student's perceptions of mathematics, learners showed strong emotions and, in some cases, a complex thought process of their feelings around math. It is a tool for educators to learn things about their students that might not be expressed in day-to-day interactions. Learners develop strong feelings and emotions about mathematics and their experiences in the classroom. Even in a short ten-to-fifteen-minute exercise a glimpse into those attitudes and feelings can be captured. It is critical to recognize and know how students feel about mathematics because emotions and feelings around math influence math identity but also the research around anxiety and its impact on learning (Boaler, 2016; Dowker et al., 2019; Ganley & McGraw, 2016) combined with the impact of emotions on learning (Hascher, 2010).

There was a significant difference in positive, negative, and neutral emotions in early elementary compared to upper elementary. In general, depictions of students with positive emotions decreased from K-2 compared to 3-5, while negative emotions increased. This could be impacted by the coding and the increase in students with emotions that cannot be discerned, which was most prevalent in fifth grade. However, the qualitative review supported what was seen in the quantitative data showing negative emotions increasing over the grades. In reviews of written messages about emotions in drawings there are also more negative than positive words written. Prior to third grade, there were few drawings with written expressions related to emotions, "easy" was written in one drawing in first grade. However, in third grade, there were six with positive words/phrases, six drawings with negative, and one with “???”. Phrases included “math is the best”, “I’m tired”, “really, really, fun awesome!”, and “stress”. Some words were contained within speech or thought bubbles while others were just written around the image. In looking at fourth and fifth grade the phrases and words were only negative. “The decline of enjoyment is not only detrimental for school learning but for a person’s academic development in general because students’ negative attitudes towards learning also will impede future learning processes” (Hascher, 2010, p. 23).

Sam’s drawing, in Table 9 and Appendix F, shows negative emotions punctuated with emphasis and question marks after the words “fun” and “satisfying”. In looking at the competing thoughts students are having about math and math class; one can wonder what this student grappling with in terms of how they feel about math. It is evident from drawings that learners have strong feelings about math, and some appear to be questioning if math can be something else. The sadness is felt through seeing a classroom scene with multiple students in tears. Words like “stress” and “bored” with “zzzzzz” and counting sheep provide clear messages and strong statements on students’ feelings (see Appendix G). Drawings with negative words included students with visibly negative emotions depicted, however, the drawings with written positive emotions did not show students in drawings with facial features or ways to recognize the emotions. Closely looking at the words in conjunction with the frowns in the drawing allowed the different reasons for the sadness to be clear, for one student it was because math was easy and for another, it was because math was hard (see Appendix G). This research further supports what others have found; both that emotions are discernable in drawings, and that positive emotions around mathematics tend to decrease throughout their school career while negative emotions tend to increase (Dowker et al., 2019; Hascher, 2010).

Access to Equitable Math Instruction

The variety of experiences and activities within math class alone shows aspects of accessibility. There was variability in the multiple activities and components within the student drawings of math class. Sometimes this variability was within a single day/class, while other times it was in the form of different activities presumably on different days or with students doing various activities within the classroom (see Appendix G). This variation of what students are doing could be one piece of responsive teaching which is important for instruction (Darling-Hammond & Oakes, 2019; Delaney & Mayer, 2021; Hawkins, 2002; Kolb, 2015; Roosevelt & Garrison, 2018; Tapper, 2012) and/or incorporation of different elements to build conceptual understanding – including discourse, inquiry, collaboration, and practice (Ball, 2000; Darling-Hammond & Oakes, 2019; Delaney & Mayer, 2021; Kolb, 2015; National Council of Teachers of Mathematics, 2014; Tapper, 2012).

Second, the drawings showed seating arrangements, tools, environmental messaging, and to a degree access to learning communities, providing a glimpse of the access students had to the space. Content and practice standards along with skills needed for a global world demand that instruction change in math class so students can meet the expectations and have skills that will serve them as problem solvers, collaborators, and critical thinkers in the world (Boaler, 2016; Common Core State Standards, 2010; Huinker, 2020; Kolb, 2015; Mehta & Fine, 2019; National Council of Teachers of Mathematics, 2018; Waks, 2013; World Economic Forum, 2020). This means that consideration must be given to the classroom environment to determine if it provides those experiences while supporting learners in developing positive associations with learning, perseverance, and recognizing they can learn.

Furniture is another aspect of a classroom that can make a student feel like they belong and have access to the space physically. Nontraditional furniture was depicted and labeled in the form of bean bag, and standing desks and couches, demonstrated some ways there is flexibility and accessibility if students have choices in where they work in the classroom. This could be very helpful for some students to have these options available to increase their attention, thinking, and focus.

While whiteboard/smartboards are in most if not all classrooms, they were not depicted equally across all grades. There were significantly more whiteboard/smartboards in upper elementary grades. This could demonstrate instructional shifts, and therefore different experiences in upper elementary that include instruction at the board more consistently or with less variation than younger grades. The use of rugs as instructional spaces also changed over time and might be another example of differences in learning experiences. In upper grades there were many rugs shown as part of the classroom environment but not an instructional space like they were in the early elementary grades. How math is taught can open access to mathematics as instruction can provide opportunities for engagement, thinking, and collaboration or limit them (Boaler, 2016).

Third, the type of math represented, and the connections made can be related to access to mathematics understanding in the classroom. Not all drawings included "mathematics" per se. Often when students were writing on paper there was nothing visible, the same was true for the students on computers. A few papers did show problems which were mostly equations to solve. The mathematics representation came in the form of equations or numbers, with fewer visual representations and no representations of word/story problems. It is unclear if this is due, in part, to student preference, frequency of exposure and time focused on them in the classroom, or if they are perceived as easier to represent in drawings. This may suggest that calculation and equations are more commonly associated with mathematics by these students, or they are more common in their math learning experiences. Although equations were the most common depiction of mathematics in drawings, calculations were low on the teacher's list when defining "What is math?" This could represent a disconnect between the learning environment, the experience students have, and the beliefs that teachers hold about mathematics.

Equations alone, if they are representative of only fact fluency instruction are an example of how math is used as a gatekeeper - through tracking and access to classes, and through testing that elevates mathematics with great power while reinforcing deficit focus (Gutiérrez, 2013). Equitable math classrooms provide access through the use of effective instructional practices that are focused on understanding and making meaning of the world (Huinker, 2020; National Council of Teachers of Mathematics, 2018) . Teachers second most highly reported "in or for understanding the world.". From this study, this connection of mathematics to the world was not depicted in student experiences.

An area where the teacher's responses aligned with what students represented was the expression of visual models and manipulatives. Manipulatives and hands-on tools (9%), as well as visual representations (7%), were not frequently shown in drawings, and Models/CRA (Concrete, Representational, Abstract) were only noted in 7% of teacher responses. No manipulatives are shown after third grade. Meaning-making and understanding are done through models and visuals are also a way of communicating ideas/thinking (National Council of Teachers of Mathematics, 2014b; Tapper, 2012), therefore their absence can become a barrier to learning and the development of conceptual understanding.

Access to understanding grade-level content is essential. In alignment with the importance of understanding quantity and the kindergarten standards, counting was prevalent in high numbers of kindergarten drawings. These representations of mathematics in student drawings, both the equations and counting, were numeral based and limited in representations of visuals or hands-on manipulatives for students to be working them with during math class. While the relevant grade-level content was represented, there was not often a depiction of math being done through models, visuals, or hands-on materials which is also essential (Huinker, 2020; Huinker & Bill, 2017; National Council of Teachers of Mathematics, 2014b, 2018; Tapper, 2012).

When looking at math content it is noteworthy that there was a difference in the representation of addition and multiplication as compared to subtraction and division. Multiplication and addition are represented twice or more than twice as often as the inverse operations of division and subtraction. As this data is skewed in this direction future research should consider possible reasons for this discrepancy. More information is needed to determine if this is representative of a lack of connection between the inverse operations, a dominance of one in instruction, a separation of these operations during instruction, or is the type of math that the student is most confident in and therefore is what they represented.

Fourth, like the lack of manipulatives and visuals, there was little evidence of communication – speaking or collaborating in the drawings. Low collaboration serves as an example of the connection between teacher's beliefs and pedagogy have on students' experiences (Aguirre et al., 2013; Bagger et al., 2020; Gonzalez, 2023). Although collaboration is key for constructing knowledge (Ball, 2000; Darling-Hammond & Oakes, 2019; Delaney & Mayer, 2021; Hima et al., 2019; Kolb, 2015; Lambert & Tan, 2020) here there were only a small number of drawings showing students working together.

Collaboration is a needed component for equitable access to math instruction (National Council of Supervisors of Mathematics & TODOS: Mathematics for ALL, 2016; National Council of Teachers of Mathematics, 2014a) and is critical for deep learning as it is a social process (Dewey, 2001; Farnsworth et al., 2016). It was not the experience of most students in BSD.

Most drawings depict students working independently at desks, as seen in Table 6. Most grades had clustered desks, which provides the opportunity to make collaboration and communication easier. Despite this there was low prevalence of student-to-student communication in the drawings. The frequency with which students were drawn sitting alone at desks or even working independently when at the same table reinforces that collaboration is not strongly represented in the drawings. As noted, this was consistent with collaboration being infrequently named by teachers.

The discrepancy might be, in adherence to the codebook, due to the fact that there were limited drawings evidence within the drawings that communication was taking place between the students even if they were sitting at the same workspace. Instead, as evidenced by the separate papers and/or computers in front of the student, it might be in fact showing independent work time. It could also be the result of student interpretation of the prompts to "Draw a picture of your math class" and how the directions and prompts were given to their class.

Alternatively, the discrepancy may suggest that collaboration and group work is not a large part of math instruction. Collaboration and group work might not be something that teachers put into practice as often and therefore is not something that learners see as representative of learners’ math experiences. It might be that it is an action that is more difficult to capture in a drawing for young students so it might be underrepresented in that way. For students to develop skills to prepare them for problem-solving in the world, at work for social justice, they need to practice and cultivate collaboration skills (Ball, 2000; Darling-Hammond & Oakes, 2019; Delaney & Mayer, 2021; Kolb, 2015; Mehta & Fine, 2019; Waks, 2013; World Economic Forum, 2020)

Lastly, as classroom instruction drives learning opportunities and access to deep learning. There was a significant difference in where the teacher was working - front of room, at desk, on the rug. This study doesn't provide insight into the impact or rational behind the differences, or what type of instruction is taking place, it is just apparent there are increasingly more teachers shown at the board/front of the room.

In these examples, there could have been the traditional vision of math instruction with the teacher telling students what to do, it could have been a whole class lesson introduction where there would be opportunity for learners to engage and problem solve, or it could have been a conversation to look at strategies and share thinking.

The qualitative review (see Appendix G) with multiple strategies being sought and/or represented to solve a problem, provides another suggestion of what instruction might be taking place. Discussing multiple strategies opens up access to mathematical understanding and which is aligned to the flexibility of thinking and problem solving (Bay-Williams & SanGiovanni, 2021; Common Core State Standards, 2010; Huinker, 2020; The Hunt Institute, 2015). This exemplifies how discourse using the effective teaching practice of comparing and connecting models and strategies might look.

Based on the relatively higher percentage of drawings with teachers working with the whole group the data suggests that this is more associated with learner's perceptions of their math class. The dominant representation of math class was working individually, without a teacher, or as part of a whole class lesson with the teacher leading the lesson.

Despite some drawings clearly demonstrating instructional practices needed for equitable access to understanding, it was not the experience all leaners portrayed. These big ideas identified for deep learning, did not show up frequently in students' depictions of math class. Given the importance it would be expected to have seen more of this represented in the student drawings, as it would be important that they see discourse, collaboration, tools and visuals as all part of math (Huinker, 2020; National Council of Teachers of Mathematics, 2014b, 2018).

Implications for instruction

This study in conjunction with research and literature on equitable instruction and identity development provide implications for instruction. These findings are categorized into these four areas:

1. Understanding learner's emotions
2. District and teacher reflection
3. Building relationships
4. Designing teacher training and professional development

Understanding learner's emotions

This study supports what other researchers have found; drawings provide a valuable tool to information on student emotions. Awareness of learners emotions and attitudes is critical as they impact learning (Boylan, 2016; Buckley et al., 2016; D'Agostin, 2014.; Hascher, 2010; Jameson, 2014; Tomasetto et al., 2021). This follows what researchers have found in the importance of teachers knowing students, recognizing their knowledge, valuing their identities, and having empathy, all key aspects of build strong relationships with learners (Ball, 2000; Gay, 2002; Kolb, 2015; Mehta & Fine, 2019; Roosevelt & Garrison, 2018). Strong relationships and understanding of students allow for creation of opportunities for deep learning (Annamma & Winn, 2019; Ball, 2000; Gay, 2002; Kolb, 2015; Mehta & Fine, 2019). It is possible that students may not articulate their emotions but might communicate their feelings through drawings which can aid in understanding what is behind the outward expressions that teachers can see.

Student emotions shape math identity and have been found to impact learning as well (Hascher, 2010). Researchers have noted that understanding not only how learners feel but the reason(s) behind those feelings can provide more insight (D'Agostin, 2014.; Garcia-Olp et al., 2017; Jameson, 2014; Martin, 2000a; Paris & Alim, 2017; Tomasetto et al., 2021) that can impact teachers' decision making. A student who is sad and frustrated would need a different response than a student who is sad because they are bored and unchallenged in class, both of which were depicted in the data. This study has demonstrated how this drawing tool provides qualitative observations which offer insight into reasons and thoughts behind some learners' emotions. Several learners' express boredom either explicitly writing I'm bored or suggested through "zzz" and counting sheep.

Observations alone do not provide that insight, without asking learners themselves there is not a way to know root causes of the feelings being expressed, to understand how students feel they must be asked (Martin, 2000).

> [T]he benefits of this approach may lie in its potential to foster teachers' continued interest in and sensitivity to their students' perceptions of the school experience. It is

> apparent that students are willing to participate in this kind of "conversation" about educational reform (Gamradt and Staples, 2023, p. p. 48)

It is common practice to focus on students' scores, results, and progress in the classroom, yet reflection on experiences, emotions, and identity is equally valuable. It is the learners that classroom environments are designed for. Drawings are a tool to build empathy and understanding. In addition, this approach can provide information that might not otherwise be known in an accessible, equitable, and low-threatening way for students to respond via drawings. Taking time to gain learner's perspectives on mathematics is an important aspect of building and strengthening personal relationships with them (Ball, 2000; Kolb, 2015; Mehta & Fine, 2019).

District and Teacher Reflection

Drawings are one tool that can be used to easily capture learner's perspectives that can then be used for teacher, school, and district reflection on math class. Data can be used to consider not only what students might need, but also to consider access to the space, the content, and the skills for every learner. As evidenced by this study, low instances of visuals, manipulatives, discourse, and collaboration in drawings were in line with the teacher survey responses. However, it sits in contrast with the literature on effective instructional practices (Common Core State Standards, 2010; Huinker, 2020; National Council of Teachers of Mathematics, 2014a, 2014b, 2018; Tapper, 2012). This is one example where a data source, student drawings, can highlight what aspects of standards are present in instruction and which might be lacking.

Another essential aspect of instruction is teacher reflection (Darling-Hammond & Oakes, 2019; Ladson-Billings, 2017; Mehta & Fine, 2019) recognizing pedagogy and practice, what goals and values in math are held, and consideration if they align with student experiences.

Research suggests that teacher reflection is important to consider in how theory and practice are being integrated into accessible instruction within the classroom (Darling-Hammond & Oakes, 2019; del Carmen Salazar, 2013; Loughran, 2006; Martin, 2000; Miller & Shifflet, 2016; Roosevelt & Garrison, 2018; Tatum, 2017). The value of reflection is evident in this study, considering how teacher goals and intents of instruction are experienced and embraced by learners as defining "math learning." While visuals, collaboration, and manipulatives were matched between teacher responses and learner depictions, there were other areas where there was no alignment between students and teachers. For example, calculations were noted by few teachers however equations were frequently shown in learners' drawings. A review of drawing data is one tool for teachers to consider what aspects of their pedagogy and instruction are resonating with their students to reveal intent and impact in instruction. Seeing how someone else views an experience also provides more perspectives to consider than the teacher's own experience and thoughts about an experience. It offers another data point to the self-reflection that is important for consideration about accessibility for students and how pedagogy is put into practice.

Educators should reflect on their own emotions and feelings about mathematics as well. In this study, learners who portrayed their teachers did so with fewer negative emotions (3%) than teachers expressed themselves (20%). As noted previously, negative attitudes can impact learning and influence beliefs students hold about mathematics and themselves as mathematicians (Boaler, 2016; Buckley et al., 2016; D'Agostin, 2014.; Hascher, 2010; Jameson, 2014; Tomasetto et al., 2021). While it is helpful that teachers may have been able to mask some of the negative emotions, more reflection is needed to see what ways these feelings and values around mathematics may be creeping into other types of interactions and instruction that could be unintentionally sending messages to learners. This is necessary as identity impacts learning and teaching (Aguirre et al., 2013; Gonzalez, 2023; Martin, 2000) therefore it is essential for educators to be aware of their emotions and how they are conveyed or perceived by learners.

Relationships

One essential aspect in classrooms is building relationships, this study shows that using drawings to elicit learner's feelings and thoughts about mathematics is another tool to foster those relationships (Hawkins, 2002; Roosevelt & Garrison, 2018). Those relationships are evident in a few drawings where students and teachers are talking, or where students are engaging in discussion with one another. Strong relationships promote the safe space for learners to be vulnerable as they engage with learning. Depictions of conversations were limited in the drawings, however, in those that did interactions there are suggestions of safe relationships established with their peers and teacher. In one positive interaction a student is depicted asking "Can you help me?" and the teacher responded "yes."

Design of teacher training and professional development

The findings from this study also provide implications for teacher training and professional development. Ensuring that there is an understanding of what skills, content, or mathematical practices are needed for more equitable instruction, and how to define success beyond correct answers alone to ensure a strengths-based approach. Collaboratively building a vision of characteristics, to become part of teachers' values and view of mathematics, to support them in making the needed shifts in practice. Ideally, over time there would be more evidence of the "learners' experience", with more commonalities of what the broader view of math and math learning experiences are like for learners. The scarcity of visuals in both the teacher and learner data sets of this study, suggests that more emphasis on the critical value visuals hold in teaching for conceptual understanding would be a logical next step in professional learning opportunities within BSD. Widening the view of mathematics and who can do mathematics in a way to humanize learners' (Gonzalez, 2023; Martin, 2000; Paris & Alim, 2017).

Future Research

This study added to the existing research on math identity and instruction. It reinforced findings in literature, expanded upon the focus of the emotional aspect of mathematical identity and contributed learners' perspectives on how math class is experienced. While this study provided insight and captured learners' experiences, allowing their perspectives to contribute to the gaps in research, there continue to be questions that arise from the data and limitations of this study. These questions could be considered for future study to continue to expand the narratives of learners in math education research.

The drawings are a glimpse into experiences. As noted, drawings ranged from a face or single person to an entire classroom with multiple classroom scenes or multiple areas of the classroom represented. Some were sectioned to depict different activities, possibly different days, or sequenced images to describe the flow of math class. Other drawings looked like the school with outside elements portrayed. Therefore, further research could consider these differences and triangulate the data with visits to the classroom or with interviews. Examining if the variation is within a day over time can deepen understanding of learner's experiences.

Drawings could become a tool during the interviews with students. Rather than asking questions about math class in general or a "typical" day, the prompt "Tell me about his drawing" provides a different format to engage in the conversation. It allows the learner to control the direction of the conversation. Interviews or focus groups with this artifact as a conversation starter and allows follow up questions and specifics to learn more about learners' perspectives and find out why they depicted particular scenes or mathematics in their drawings.

Another possibility for further research is to explore a series of drawings and consider the variability of math class experiences and emotional shifts over time. A series of drawings - like research has done a series of photos – could provide insight as to what math look like across time for learners. It could be in a week or spread over a year to explore different questions about their experiences learning. This could capture how their experience and identity shift and evolve over time.

As this research focused on aspects within a school environment and how that contributes to math identity and learning, there is an opportunity for future research to bridge the influences beyond schools to consider their influence on development. Learners could document math experiences in and out of school - or document where and how they use math in different parts of their lives. This research could increase awareness to the broader purposes of math, and not only the narrower view of "school math". In addition, it would be powerful to engage in researching how factors outside the classroom are impacting student's attitudes, experiences, and influences relate to their relationship and identity around mathematics. Under this umbrella, better understanding the knowledge and experiences that communities and community members hold would be important. Having discussions on the emotions expressed about mathematics, and considering how math is depicted across different settings. The comparison of "school math" and "math in the world", or the various emotions across settings would both provide further insight into how mathematics is characterized and defined. In addition to, the emotions and influential experiences that are at play the formation of mathematical identity.

While the data did not include enough information on the many identities that the individual learners hold, it allowed the focus to be on the details of the drawings. This highlighted the emotions and expression around feelings of mathematics. There is recognition that "Emotions are complex things and are strongly interwoven with cognition and motivation." p14, and further research would be beneficial in connecting this to the growing studies on emotion (Hascher, 2010). Additional research on anxiety and identity, can open a conversation between the different emotional aspects, anxiety and more, and mathematical identity. Integrating what has been learned from math anxiety research and expand exploration of other emotions and their relationship with learning and identity would strengthen understanding of learner's emotions as they relate to identity formation and the act of learning mathematics.

Furthermore, as the general student community is predominately white this collection of experiences may not be the same across all demographics, especially as the phenomena of math class experience is so unique to individuals. Questions remain. How are the students of color experiencing math class in BSD? How do students in other communities' experience math class? To build more student voices and experiences continued research can be done with more racially diverse populations, or this study could be repeated with the inclusion of demographics of the learners to provide the information that was not available in this study.

Reflection

Mathematical identity formation is influenced by history, culture, society, and community through societal norms, expectations, and interactions (Leyva et al., 2021; Martin, 2000). While these outside factors are affecting individuals, at the same time individuals are shaping how community, culture, and history evolve (Martin, 2000). Within a learner's community, schools and teachers are impacting one another and influencing the mathematical identity the learners embrace. This was the focus of this study.

While this study does not directly address race, it does present data from a predominantly white community, and therefore the majority of experiences were representing a white learner's perspective. The community also has diversity within socioeconomic class, student services and educational labels (ML, IEP, 504, EST plans). All of which are impacting factors on academic success, access to learning, and access to positive math identities. These intersections of identity and the connections they have to learner's perceptions on experiences are beyond the scope of this study. The study utilizes the data to focus on the emotional aspect. An important future research step to integrate data with more demographics to be able to recognize and name the stories with the full identity of the learners recognized. With this data set and the anonymity of the data, tensions that could exist in learner's experiences between their identities and norms, values, and community may remain hidden. Adding demographic information, or student self-identifying their identities has the potential to make this more visible within the math education and social justice conversation.

Learner identity is continuously evolving, and the aspects of identity which are expressed are influenced by both the environment and interactions with people (Gresalfi & Cobb, 2011; Martin, 2000; Paris & Alim, 2017). Not knowing the individual identities of the learners was one limitation. However, this provided the benefit of looking exclusively at the drawings, which resulted in the narrowing of the components of identity that were considered. Had multiple aspects been part of the data, some stories or details may not have become central. The focus became self-perception and emotions within a math class experience. There were significant differences in emotions from early and upper elementary students. There were significant differences in student emotions represented when compared to the emotions expressed by teachers. Acknowledging and reflecting on the emotions of students and of educators is critical as feelings influence learning.

A future research direction needed to increase access for all students is further exploration of math identity and emotions concerning their impact on learning. Also, it is worth looking into the rationale behind who learners include in the drawings, as in this study frequently students were left out of drawings or when they were present, they did not have faces/expressions drawn. Understanding the reason behind student decisions about how to represent their mathematics experience can be insightful. The root cause of this is not known, it could be due to the prompt and no mention of drawing oneself or people in math class, it could also be influenced by teachers administering the drawing, where students may be apprehensive about their teachers viewing them. Another possibility could be that students expressing positive emotions didn't feel the need to justify it with student expressions. Possibly learners with negative emotions thought they had to explain and prove their experience and emotions, as it was noted that negative drawings had more writing connected to emotions as well. These variables should be considered in using this and other drawing tools in the future, both to help determine which prompts to use and to provide the representation that best matches the research question at hand.

Consideration to the codes in the codebook could also be considered, to ensure that the data is best aligned to the research question and purpose of data collection. This study utilized existing data and an existing codebook, which provided a validated instrument, yet also presented some challenges. Having knowledge of elementary school classrooms was beneficial in coding. Background knowledge of math programs and instructional practices made components like their number paths, workplaces (as labeled by students) and number corner elements recognizable and easier to code. Furthermore, it helped to decipher the drawings and recognize familiar elements, pocket charts and such. After reviewing the data and details in the drawing, some codes could be added that would provide a way to capture and include all visuals, not only arrays or dot cards, within the count of attributes. Explicitly coding for equations as opposed to other problem types would also allow more analysis and acknowledgement of how math is portrayed and how learners are engaging with the learning with additional qualitative details. This would not only provide more insight but also accuracy of what learners depict in their learning environment as more information would be captured in the coding.

The research questions for this study evolved over time. In reviewing the data, it was clear that examining K-2 to 3-5 was not where the most interesting data or stories were told. Rather, the details within the grade level data were of greater interest and maintained the nuances of the data that were hidden when the data was grouped by grade span. Partly this could have been influenced by the fact that the total number of drawings varied greatly from grade to grade so a more robust data set for each grade would have eased reflection and analysis of drawings.

The data highlighted aspects that are critical characteristics of equitable instruction, based on literature and characteristics defined by mathematics education organizations as critical for access and equity and deep learning, that are lacking in teacher definitions of mathematics and learners' representations of their experiences. While this is one small data set of a moment in time, few drawings depicted manipulatives/hands-on tools, visuals, or captured communication which are all identified as essential for deep learning (Common Core State Standards, 2010; Huinker, 2020; National Council of Teachers of Mathematics, 2018; Tapper, 2012). This is a critical area to consider regarding equitable access for all learners. Especially as modeling is one of the mathematical practices, and the use of strategies and visuals is highlighted in standards (Common Core State Standards, 2010) , it was surprising that this feature was not common among the drawings. Visuals and manipulatives, unlike communication, are also easier to draw so the mode of the survey should not have impacted the ability of students to express these components if they envision them as central to their math class experience.

Recognizing the factors that contribute to differences in learning experiences for students, and impact development of mathematical identity it is necessary to reflect and respond in a manner to shift practices. Deficit focus, labels, and norms (such as ableism, racism, and normalization of English) lead to lower expectations and different experiences for students who identify or are placed in particular groups or categories (Aguirre et al., 2013; Boaler, 2016; Chronaki, 2017; Gonzalez, 2023; Martin, 2000; Smith et al., 2021). For equitable access reflection, both an individual and systemic perspective is needed, to create more equitable learning opportunities.

References

18 Questions on social learning theory. (2010). https://www.wenger-trayner.com/etienne#archive

Abdulah, D. M., Abdulla, B. M. O., & Liamputtong, P. (2021). Psychological response of children to home confinement during COVID-19: A qualitative arts-based research. *International Journal of Social Psychiatry*, *67*(6), 761–769. https://doi.org/10.1177/0020764020972439

Aguirre, J. (2022, April). *Grades and test scores do not define us as math learners: Cultivating transformative spaces for anti-racist mathematics education*. Leveraging the Mathematical Brillance of Students. https://www.nctm.org/online-learning/Webinars/Details/608

Aguirre, J. M., Mayfield-Ingram, K., & Martin, D. B. (2013a). *The impact of identity in K-8 mathematics learning and teaching:Rethinking equity-based practices*. The National Council of Teachers of Mathematics, Inc.

Allison, P., & Pomeroy, E. (2000). How shall we "know?" epistemological concerns in research in experiential education. *Journal of Experiential Education*, *23*(2), 91–98. https://doi.org/10.1177/105382590002300207

Annamma, S. A., & Winn, M. (2019). Transforming our mission: Animating teacher education through intersectional justice. *Theory Into Practice*, *58*(4), 318–327. https://doi.org/10.1080/00405841.2019.1626618

Armstrong, T. (2010). *The power of neurodiversity unleashing the advantages of your differently wired brain*. Da Capo Press.

Bagger, A., Roos, H., & Engvall, M. (2020). Directions of intentionalities in special needs education in mathematics. *Educational Studies in Mathematics*, *104*(1), 41–58. https://doi.org/10.1007/s10649-020-09945-4

Ball, A. F. (2000). Teachers' developing philosophies on literacy and their use in urban schools: A Vygotskian perspective on internal activity and teacher change. In C. D. Lee & P. Smagorinsky (Eds.), *Vygotskian perspectives on literacy research: Constructing meaning through collaborative inquiry* (pp. 226–255). Cambridge University Press.

Battey, D., & Leyva, L. A. (2016). *A framework for understanding whiteness in mathematics education*. *9*(2), 32.

Bay-Williams, J. M., & SanGiovanni, J. J. (2021). *Figuring out fluency in mathematics teaching and learning, grades K-8: Moving beyond basic facts and memorization*. Corwin.

Belotto, M. (2018). Data Analysis Methods for Qualitative Research: Managing the Challenges of Coding, Interrater Reliability, and Thematic Analysis. *The Qualitative Report*. https://doi.org/10.46743/2160-3715/2018.3492

Boaler, J. (2016). *Mathematical mindsets:Unleashing students' potential through creative math, inspiring messages and innovative teaching*. Jossey-Bass A Wiley Brand.

Bowman, J. A., McDonnell, J., Ryan, J. H., & Fudge-Coleman, O. (2019). Effective mathematics instruction for students with moderate and severe disabilities: A review of the literature. *Focus on Autism and Other Developmental Disabilities*, *34*(4), 195–204. https://doi.org/10.1177/1088357619827932

Boylan,Mark. (2016). Ethical dimensions of mathematics education. *Educational Studies in Mathematics*, *92*(3), 395–409. https://doi.org/DOI 10.1007/s10649-015-9678-z

Buckley, S., Reid, K., Goos, M., Lipp, O. V., & Thomson, S. (2016). Understanding and addressing mathematics anxiety using perspectives from education, psychology and neuroscience. *Australian Journal of Education*, *60*(2), 157–170. https://doi.org/10.1177/0004944116653000

Childs, K. (2022). *Becoming a mathematics focused social justice educator*. NCTM Annual Meeting & Exposition.

Chronaki, A. (2017). Mathematics education as a matter of Identity. In *Encyclopedia of educational philosophy and theory—Credo reference* (1st ed.). Springer Science & Business Media. https://search-credoreference-com.ezproxyles.flo.org/content/entry/sprepat/mathematics_education_as_a_matter_of_identity/0#ch_13_CR13256

Cioè-Peña, M. (2021). Raciolinguistics and the Education of Emergent Bilinguals Labeled as Disabled. *The Urban Review*, *53*(3), 443–469. https://doi.org/10.1007/s11256-020-00581-z

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

Common Core State Standards. (2010). *Common core state standards for mathematics*. Common Core State Standards Initiative. https://learning.ccsso.org/wp-content/uploads/2022/11/ADA-Compliant-Math-Standards.pdf

Crabtree, B., & Miller, W. (1999). A template approach to text analysis: Developing and using codebooks. In *Doing qualitative research* (pp. 163–177). SAGE Publications.

Crenshaw, K. (2016, December 7). *The urgency of intersectionality [Video]*. YouTube. https://www.youtube.com/watch?v=akOe5-UsQ2o

Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry & research design: Choosing among five approaches*. Sage Publications.

D’Agostin, F. (2014). *The value of emoticons in investigating student emotions related to mathematics task negotiation*. Mathematics Education Research Group of Australasia

Daley, T. C., & Weisner, T. S. (2003). “I speak a different dialect”: Teen explanatory models of difference and disability. *Medical Anthropology Quarterly*, *17*(1), 25–48.

Darling-Hammond, L., & Oakes, J. (2019). *Preparing teachers for deeper learning*. Harvard Education Press.

DeJarnette, A. F., Wilke, E., & Hord, C. (2020). Categorizing mathematics teachers’ questioning: The demands and contributions of teachers’ questions. *International Journal of Educational Research*, *104*, 1–20. https://doi.org/10.1016/j.ijer.2020.101690

del Carmen Salazar, M. (2013). A humanizing pedagogy: Reinventing the principles and practice of education as a journey toward liberation. *Review of Research in Education*, *37*(1), 121–148. https://doi.org/10.3102/0091732X12464032

Delaney, M. K., & Mayer, S. J. (Eds.). (2021). *In search of wonderful ideas: Critical exploration in teacher education*. Teacher College Press.

Dewey, J. (2001). *Democracy and education*. The Pennsylvania State University.

Dowker, A., Cheriton, O., Horton, R., & Mark, W. (2019). Relationships between attitudes and performance in young children’s mathematics. *Educational Studies in Mathematics*, *100*(3), 211–230. https://doi.org/10.1007/s10649-019-9880-5

Duckworth, E. (1987). *“The having of wonderful ideas” & other essays on teaching & learning*. Teachers College Press.

Dweck, C. S. (2006). *Mindset: The new psychology of success* (1st ed). Random House.

Farnsworth, V., Kleanthous, I., & Wenger-Trayner, E. (2016). Communities of practice as a social theory of learning: A conversation with Etienne Wenger. *British Journal of Educational Studies*, *64*(2), 139–160. https://doi.org/10.1080/00071005.2015.1133799

Freire, P. (2000). *Pedagogy of the oppressed* (30th anniversary ed). Continuum.

Gamradt, J., & Staples, C. (2023). *My School and Me: Children's Drawings in Postmodern Educational Research and Evaluation*.

Ganley, C. M., & McGraw, A. L. (2016). The Development and Validation of a Revised Version of the Math Anxiety Scale for Young Children. *Frontiers in Psychology*, *7*. https://doi.org/10.3389/fpsyg.2016.01181

Garcia-Olp, M., Ooyik, J. V., & Kitchen, R. (2017). Deficit discourse and labeling in elementary mathematics classrooms. *Journal of Mathematics Education at Teachers College*, *8*(2), Article 2. https://doi.org/10.7916/jmetc.v8i2.590

Gay, G. (2002). Preparing for culturally responsive teaching. *Journal of Teacher Education*, *53*(2), 106–116. https://doi.org/10.1177/0022487102053002003

Gibbs, A. S., Hinton, V. M., & Flores, M. M. (2018). A case study using CRA to teach students with disabilities to count using flexible numbers: Applying skip counting to multiplication. *Preventing School Failure*, *62*(1), 49–57. https://doi.org/10.1080/1045988X.2017.1342218

Gonzalez, L. (2023). *Bad at math? Dismantling harmful beliefs that hinder equitable mathematics education*. Corwin.

Gresalfi, M. S., & Cobb, P. (2011). Negotiating identities for mathematics teaching in the context of professional development. *Journal for Research in Mathematics Education*, *42*(3), 270–304. https://doi.org/10.5951/jresematheduc.42.3.0270

Gutiérrez, R. (2013). The sociopolitical turn in mathematics education. *Journal for Research in Mathematics Education*, *44*(1), 37–68. https://doi.org/10.5951/jresematheduc.44.1.0037

Gutiérrez, R., Myers, M., & Kokka, K. (2023). The stories we tell: Why unpacking narratives of mathematics is important for teacher conocimiento. *The Journal of Mathematical Behavior*, *70*, 101025. https://doi.org/10.1016/j.jmathb.2022.101025

Gutstein, E. (2016). "Our issues, our people—Math as our weapon"? Critical mathematics in a Chicago neighborhood high school. *Journal for Research in Mathematics Education*, *47*(5), 454–504.

Gutstein, E., Middleton, J., Fey, J., Larson, M., Heid, M. K., Dougherty, B., DeLoach-Johnson, I., & Tunis, H. (2005). Equity in school mathematics education: How can research contribute? *Journal for Research in Mathematics Education*, *36*(2), 92–100. https://doi.org/10.2307/30034826

Guzmán, L. D. (2019). Beyond hidden figures: Shining a spotlight on constructed hierarchies of gender, age, and elementary mathematics. *Gender Issues*, *36*(4), 392–414. https://doi.org/10.1007/s12147-019-09241-3

Haney, W., Russell, M., & Bebell, D. (2004). Drawing on education: Using drawings to document schooling and support change. *Harvard Educational Review*, *74*(3), 241–272. https://doi.org/10.17763/haer.74.3.w0817u84w7452011

Hascher, T. (2010). Learning and Emotion: Perspectives for Theory and Research. *European Educational Research Journal*, *9*(1), 13–28. https://doi.org/10.2304/eerj.2010.9.1.13

Hawkins, D. (2002). *Informed vision: Essays on learning and human nature*. Algora Publishing. http://ebookcentral.proquest.com/lib/lesley/detail.action?docID=318651

Hima, L. R., Nusantara, T., Hidayanto, E., & Rahardjo, S. (2019). Changing in mathematical identity of elementary school students through group learning activities. *International Electronic Journal of Elementary Education*, *11*(5), 461–469. http://dx.doi.org.ezproxyles.flo.org/10.26822/iejee.2019553342

Hogg, M. A., Terry, D. J., & White, K. M. (1995). A tale of two theories: A critical comparison of identity theory with social identity theory. *Social Psychology Quarterly*, *58*(4), 255. https://doi.org/10.2307/2787127

Huinker, D. (Ed.). (2020). *Catalyzing change in early childhood and elementary mathematics: Initiating critical conversations*. National Council of Teachers of Mathematics.

Huinker, D., & Bill, V. (2017). *Taking action: Implementing effective mathematics teaching practices in K-grade 5*. National Council of Teachers of Mathematics.

IES National Center For Education Statistics. (2022). US Department of Education. https://nces.ed.gov/

Imm, K., Lambert, R., Moy, E., & Vitale, N. (2024). Beyond the rhetoric of "re-imagining": Using design thinking to create with and for teachers. *Mathematics Teacher Educator*, *12*(2).

Jameson, M. M. (2014). Contextual Factors Related to Math Anxiety in Second-Grade Children. *Journal of Experimental Education*, *82*(4), 518–536. https://doi.org/10.1080/00220973.2013.813367

Kendall, F. (2013). *Understanding white privilege creating pathways to authentic relationships across race* (2nd ed.). Routledge.

Keown, S. R., & Bourke, B. (2019). A qualitative investigation of fixed versus growth mindsets of third and fourth grade students. *Education*, *140*(2), 51–58.

Kitchen, R., Anderson Ridder, S., & Bolz, J. (2016). The legacy continues: "The Test" and denying access to a challenging mathematics education for historically marginalized students. *Journal of Mathematics Education at Teachers College*, Vol. 7 No. 1: Spring 2016. https://doi.org/10.7916/JMETC.V7I1.784

Kolb, D. A. (2015). *Experiential learning: Experience as the source of learning and development* (Second edition). Pearson Education, Inc.

Kuhn, D. (2008). *Education for thinking* (1. paperback ed). Harvard University Press.

Ladson-Billings, G. (2017). The (r)evolution will not be standardized: Teacher education, hip hop pedagogy, and culturally relevant pedagogy 2.0. In D. Paris & H. S. Alim (Eds.), *Culturally sustaining pedagogies: Teaching and learning for justice in a changing world* (pp. 141–156). Teachers College Press.

Lambert, R. (2022). *#DeleteDeficitThinking: How changing beliefs can transform our mathematics classrooms* (68). Retrieved October 22, 2022, from https://podcasts.apple.com/us/podcast/ncsm-leadership-in-mathematics-education-learning-with/id340703550?i=1000553679618 https://podcasts.apple.com/us/podcast/ncsm-leadership-in-mathematics-education-learning-with/id340703550?i=1000553679618

Lambert, R., & Sugita, T. (2016). Increasing engagement of students with learning disabilities in mathematical problem-solving and discussion. *Support for Learning*, *31*(4), 347–366. https://doi.org/10.1111/1467-9604.12142

Lambert, R., Sugita, T., Yeh, C., Hunt, J. H., & Brophy, S. (2020). Documenting increased participation of a student with autism in the standards for mathematical practice. *Journal of Educational Psychology*, *112*(3), 494–513. https://doi.org/10.1037/edu0000425

Lambert, R., & Tan, P. (2020). Does disability matter in mathematics educational research? A critical comparison of research on students with and without disabilities. *Mathematics Education Research Journal*, *32*(1), 5–35. http://dx.doi.org.ezproxyles.flo.org/10.1007/s13394-019-00299-6

Leavy, P. (2017). *Research design:Quantitative, qualitative, mixed methods, arts-based, and community-based participatory research approaches*. Guilford Press.

Lei, Q., Xin, Y. P., Morita-Mullaney, T., & Tzur, R. (2020). Instructional scaffolds in mathematics instruction for english learners with learning disabilities: An exploratory case study. *Learning Disabilities*, 123–144.

Leyva, L. A., McNeill, R. T., Marshall, B. L., & Guzmán, O. A. (2021). "It seems like they purposefully try to make as many kids drop": An analysis of logics and mechanisms of racial-gendered inequality in introductory mathematics instruction. *The Journal of Higher Education*, *92*(5), 784–814. https://doi.org/10.1080/00221546.2021.1879586

Loughran, J. (2006). *Developing a pedagogy of teacher education: Understanding teaching and learning about teaching*. Routledge.

Loutzenheiser, L. W., & Erevelles, N. (2019). 'What's Disability Got To Do With It?': Crippin' Educational Studies at the Intersections. *Educational Studies*, *55*(4), 375–386. https://doi.org/10.1080/00131946.2019.1630131

Mao, L., Mian Akram, A., Chovanec, D., & Underwood, M. L. (2016). Embracing the spiral: Researcher reflexivity in diverse critical methodologies. *International Journal of Qualitative Methods*, *15*(1), 1–8. https://doi.org/10.1177/1609406916681005

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

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

Mehta, J., & Fine, S. (2019). *In search of deeper learning: The quest to remake the American high school*. Harvard University Press.

Metcalfe, A. S. (2015). Visual juxtaposition as qualitative inquiry in educational research. *International Journal of Qualitative Studies in Education*, *28*(2), 151–167. https://doi.org/10.1080/09518398.2013.855340

Miller, K., & Shifflet, R. (2016). How memories of school inform preservice teachers' feared and desired selves as teachers. *Teaching and Teacher Education*, *53*, 20–29. https://doi.org/10.1016/j.tate.2015.10.002

Minnich, E. (2005). *Transforming Knowledge*. Temple University Press.

National Council of Supervisors of Mathematics, & TODOS: Mathematics for ALL. (2016). *Mathematics education through the lens of social justice: Acknowledgment, actions, and accountability*. National Council of Supervisors of Mathematics and TODOS:Mathematics for ALL. https://www.mathedleadership.org/docs/resources/positionpapers/NCSMPositionPaper16.pdf

National Council of Teachers of Mathematics. (2014a). *Access and equity in mathematics education: A position of the National Council of Teachers of Mathematics*. NCTM, National Council of Teachers of Mathematics. https://www.nctm.org/uploadedFiles/Standards_and_Positions/Position_Statements/Access_and_Equity.pdf

National Council of Teachers of Mathematics (Ed.). (2014b). *Principles to actions: Ensuring mathematical success for all*. NCTM, National Council of Teachers of Mathematics.

National Council of Teachers of Mathematics (Ed.). (2018). *Catalyzing change in high school mathematics: Initiating critical conversations*. The National Council of Teachers of Mathematics.

National Council of Teachers of Mathematics. (2023). *Ability labels: Disrupting "high," "medium," and "low" in mathematics education*. file:///Users/ericamoy/Downloads/NCTM_Ability_Labels_Position_Statement_Nov2023.pdf

National Science Foundation. (2018). *Math and Statistics Degrees* [dataset].

NCTM. (2023). *Reasoning and decision-making, not rote application of procedures position*. NCTM, National Council of Teachers of Mathematics. https://www.nctm.org/Standards-and-Positions/Position-Statements/Procedural-Fluency-in-Mathematics/

Paris, D., & Alim, H. S. (Eds.). (2017). *Culturally sustaining pedagogies: Teaching and learning for justice in a changing world*. Teachers College Press.

Parks, A. N. (2020). Centering children in mathematics education classroom research. *American Educational Research Journal*, *57*(4), 1443–1484. https://doi.org/10.3102/0002831219873853

Picker, S. H., & Berry, J. S. (2000). Investigating pupils' images of mathematicians. *Educational Studies in Mathematics*, *43*(1), 65–94. https://doi.org/10.1023/A:1017523230758

Ramis-Conde, I., & Hope, A. (2020). Training teachers in maintaining equity in the micro-moments of a mathematical dialogue. *Teaching and Teacher Education*, *87*, 1–12. https://doi.org/10.1016/j.tate.2019.102924

Reflective Education Research. (n.d.). *Drawing on math* [dataset]. https://drawingonmath.org/coding.html

Ritchie, J., Lewis, J., Elam, G., Tennant, R., & Rahim, N. (2013). Designing and Selecting Samples. In *Qualitative research practice: A guide for social science students and researchers* (pp. 111–146). Sage. https://uk.sagepub.com/en-gb/eur/qualitative-research-practice/book237434

Robertson, S.-A., & Mellony, G. (2020). Language as an including or excluding factor in mathematics teaching and learning. *Mathematics Education Research Journal*, *32*(1), 77–101. http://dx.doi.org.ezproxyles.flo.org/10.1007/s13394-019-00302-0

Roosevelt, D., & Garrison, J. (2018). “Yet the root of the matter is not in them”: Reclaiming the lost soul of inspirational teaching: Reclaiming the lost soul of inspirational teaching. *Educational Theory*, *68*(2), 177–195. https://doi.org/10.1111/edth.12305

Seda, P., & Brown, K. (2021). *Choosing to see: A framework for equity in the math classroom*. Dave Burgess Consulting Incorporated.

Smith, D., Fisher, D., & Frey, N. (2021). *Removing labels, grades K-12: 40 techniques to disrupt negative expectations about students and schools*. Corwin.

Søndergaard, E., & Reventlow, S. (2019). Drawing as a facilitating approach when conducting research among children. *International Journal of Qualitative Methods*, *18*, 160940691882255. https://doi.org/10.1177/1609406918822558

Stewart, D. L. (2017). Language of appeasement. *Inside Higher Ed*.

Stiles, D. A., Adkisson, J. L., Sebben, D., & Tamashiro, R. (2008). Pictures of hearts and daggers: Strong emotions are expressed in young adolescents drawings of their attitudes towards mathematics. *World Cultures eJournal*.

Tan, P., Lambert, R., Padilla, A., & Wieman, R. (2019). A disability studies in mathematics education review of intellectual disabilities: Directions for future inquiry and practice. *The Journal of Mathematical Behavior*, *54*, 1–13. https://doi.org/10.1016/j.jmathb.2018.09.001

Tapper, J. (2012). *Solving for why: Understanding, assessing, and teaching students who struggle with math*. Math Solutions.

Tatum, B. D. (2017). *"Why are all the black kids sitting together in the cafeteria?": And other conversations about race* (Third trade paperback edition). Basic Books.

The Hunt Institute (Director). (2015, April 7). *Building conceptual understanding in matheamtics*. https://hunt-institute.org/resources/2015/04/nctm-mathematics-video-series-building-conceptual-understanding-in-mathematics/

The myth of low kids and high kids. (2019). https://www.youtube.com/watch?v=8nQHDin3pmQ

Tomasetto, C., Morsanyi, K., Guardabassi, V., & O'Connor, P. A. (2021). Math anxiety interferes with learning novel mathematics contents in early elementary school. *Journal of Educational Psychology*, *113*(2), 315–329. https://doi.org/10.1037/edu0000602

van Garderen, D., Lannin, J. K., & Kamuru, J. (2020). Intertwining special education and mathematics education perspectives to design an intervention to improve student understanding of symbolic numerical magnitude. *The Journal of Mathematical Behavior*, *59*, 1–16. https://doi.org/10.1016/j.jmathb.2020.100782

Vomvoridi-Ivanovic, E., & McLeman, L. (2015). Mathematics teacher educators focusing on equity: Potential challenges and resolutions. *Teacher Education Quarterly*, *42*(4), 83–100.

Waks, L. J. (2013). John Dewey and the challenge of progressive education. *International Journal of Progressive Education*, *9*(1), 73–83.

Weber, N., Duncan, D., Dyehouse, M., Strobel, J., & Diefes-Dux, H. A. (2011). The Development of a Systematic Coding System for Elementary Students' Drawings of Engineers. *Journal of Pre-College Engineering Education Research (J-PEER)*, *1*(1). https://doi.org/10.7771/2157-9288.1030

Wells, G. (2000). Dialogic inquiry in education: Building on the legacy of Vygotsky. In C. D. Lee & P. Smagorinsky (Eds.), *Vygotskian perspectives on literacy research: Constructing meaning through collaborative inquiry* (pp. 51–85). Cambridge University Press.

Wink, J., & Putney, L. (2002). *A vision of Vygotsky*. Allyn and Bacon.

Woodward, J., & Tzur, R. (2017). Final commentary to the cross-disciplinary thematic special series: Special education and mathematics education. *Learning Disability Quarterly*, *40*(3), 146–151.

World Economic Forum. (2020). *Schools of the future: Defining a new model of education for the fourth industrial revolution*. Global Challenge Insight Report.

Xin, Y. P., Chiu, M. M., Tzur, R., Ma, X., Park, J. Y., & Yang, X. (2020). Linking teacher–learner discourse with mathematical reasoning of students with learning disabilities: An exploratory study. *Learning Disability Quarterly*, *43*(1), 43–56. https://doi.org/10.1177/0731948719858707

Xin, Y. P., Liu, J., Jones, S. R., Tzur, R., & Si, L. (2016). A preliminary discourse analysis of constructivist-oriented mathematics instruction for a student with learning disabilities. *Journal of Educational Research*, *109*(4), 436–447. https://doi.org/10.1080/00220671.2014.979910

Yeh, C., Ellis, M., & Mahmood, D. (2020). From the margin to the center: A framework for rehumanizing mathematics education for students with dis/abilities. *The Journal of Mathematical Behavior*, *58*, 1–11. https://doi.org/10.1016/j.jmathb.2020.100758

Zhao, P., Ross, K., Li, P., & Dennis, B. (2021). *Making sense of social research methodology: A student and practitioner centered approach*. Sage Publications.

Zhao, P., Ross, K., P, Peiwei, L., & Dennis, B. (2022). *Making sense of social research methodology: A student and practitioner centered approach* (First edition). SAGE Publications, Inc.

Appendices

Appendix A: Drawing on Math Drawing Form

Draw a picture of your Math class.

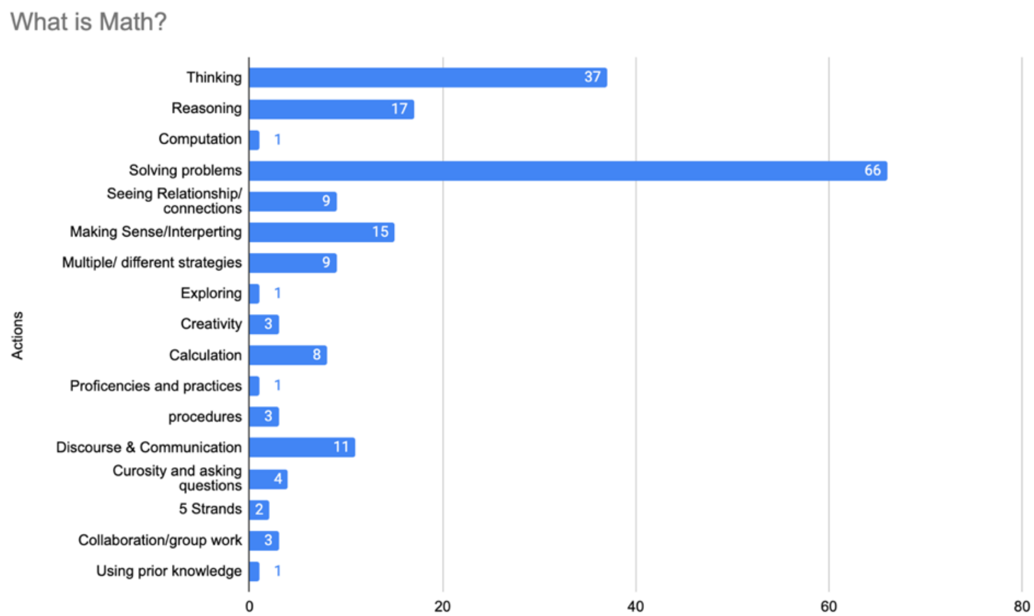
Your School:____ Grade Level:____________

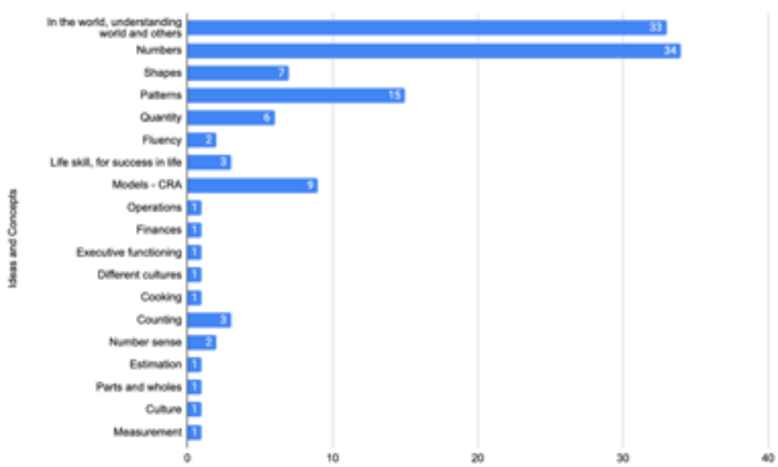
Directions to be read: "We want to know what math class is like for you so today you are going to draw a picture of math class. This is not graded. There are no right or wrong math classroom drawings. Remember you should do your own drawing and whatever you want your picture to look like is fine. You can use pencil only or add color if you want to. If you want to label important parts of your drawing or add words you can. Think about your math class and then begin drawing."

Appendix B: Drawing On Math Codes & Coding Resources

Drawing Characteristics and Operational Definition
Coding Rubric
Examples for Each Coding Characteristic

Appendix C: Teacher Survey Results





Appendix D: District Data Used in Research Study

District math audit results – The reports and results of the 2022-23 district math audit will be used for background information on the school district. It provides insight into additional information on students' experiences learning math at school as well as perceptions and feelings about learning math at school as students and staff were interviewed as part of the audit. This report also summarizes observations about math classrooms. All of this report is anonymous.

Student Drawings – Based upon a plan developed from the 2022-23 math audit, in the fall of 2023 students were asked to complete a drawing as an accessible student survey. These drawings were summarized for district staff members to review. A district staff member, not the researcher, went through each student drawing and redacted any names that were used on/in the drawings to ensure that the student drawing surveys were anonymous before they were reviewed to compile a district summary to be shared with staff.

Teacher survey results – Routinely as part of in-service days, embedded professional learning and as a means to collect input from teachers they are asked to complete anonymous surveys. This data is summarized and used to reflect on district goals, professional development, and professional learning. The results of surveys related to mathematics instruction completed in 2022-23 and fall 2023 will be used in this study.

District demographic and policy – This information is publicly available through state agencies and on the district website.

Appendix E: Results – Percentages of each feature coded

Classroom Environment Features
Percentage of feature(s) depected in the envirionment as portrayed across all drawings.

	K	1	2	3	4	5
Student desk in clusters	14	32	20	12	25	50
Student desk in rows/grid	13	21	29	39	19	6
Whiteboard/Smartboard	9	18	29	39	58	84
Rug/Carpet	21	36	18	30	25	25
Station/Centers around room	3	14	4	2	4	0
Teacher Desk	0.9	0	9	6	10	31
Kidney Shaped Tables	0	0	4	4	17	13
Classroom Decoration	5	14	9	16	8	13
Projector	0.9	0	2	0	0	0
Nontraditional Furniture	0	4	0	4	2	6

Math Tools and Technology by Grade
Percentage of math tools or technology depected as portrayed across all drawings.

	K	1	2	3	4	5
Book/Paper/Pencil	8	36	27	43	23	34
Student Whiteboards	0	0	0	1	0	0
Computer/Techonology for						
Students	0.9	14	16	17	2	9
Teachers	0.9	0	4	2	2	19
Other	0	4	0	4	4	0
Manipulatives/blocks/hands on math tools	21	4	16	1	0	0
Games	17	4	11	7	2	6
Arrays/ Visual Array	3	4	9	6	4	0
Flash Cards	0	0	0	0	0	0
Dot Cards	0.9	4	2	0	0	0
Place Value Words/ Visuals*	0.9	4	2	1	0	0

Type of Math Depicted by Grade

Percentage of drawings with each type of math depected as portrayed across all drawings.

	K	1	2	3	4	5
Addition	3	36	24	14	25	16
Subtraction	0	14	7	8	13	9
Multiplication	0	0	0	35	46	50
Division	0	0	0	12	19	13
Clocks/Calendar	0	4	9	4	6	6
Fractions/Decimals	0	0	0	1	2	0
Counting/number line	39	7	20	2	8	3
Geometry	5	0	2	2	4	3
Can't discern Math	25	25	42	16	8	21

Classroom Interactions by Grade

Percentage of interactions in drawings with students or teachers depicted.

	K	1	2	3	4	5
Students communicating with						
Other students	6	16	10	6	9	6
Teachers	3	0	7	13	4	17
Students working						
individually	21	36	18	30	25	25
in small groups	3	14	4	2	4	0
in large group	0.9	0	9	6	10	31
Teacher working						
at board/front of room	60	71	36	69	73	64
with individual student	7	14	18	6	9	21
with small group of students	20	14	27	9	9	21
with whole class	13	43	18	56	36	50

Emotions in Math Class

Percentage of emotions represented in drawings with students or teachers portrayed.

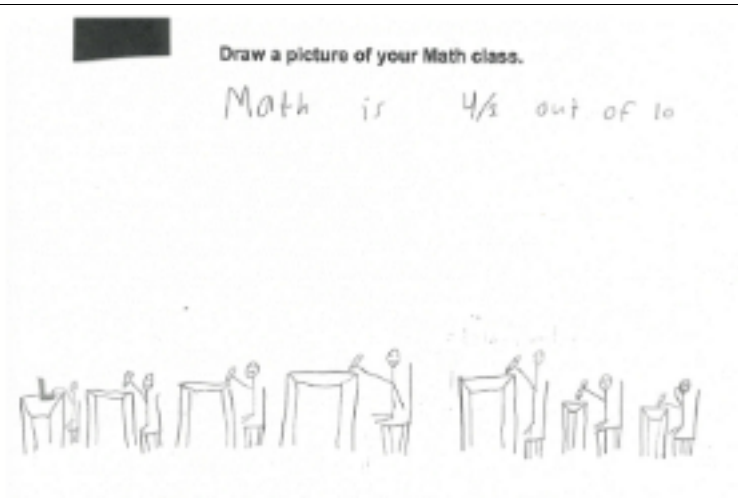
	K	1	2	3	4	5
Students depicted						
Positively	58	53	73	47	26	17
Negatively	13	5	7	20	22	0
Neutral	15	21	13	31	87	22
Can't Discern Emotion	44	58	37	50	48	83
Teachers depicted						
Positively	53	29	72	50	18	36
Negatively	0	0	0	6	0	7
Neutral	0	0	0	13	36	21
Can't Discern Emotion	47	57	55	28	45	36

Appendix F: Researcher Memos for Qualitative Review

Todd:
Todd has drawn
a face with a big frown and the word "bad" written above it. There are no other people or mathematics. This is simply a sad looking face in a box.

Jason:
Jason has depicted a student page with name and date at the top and some lines and scribbles, so an undiscernible math concept on the paper. Next to this is a smiling stick figure that is saying

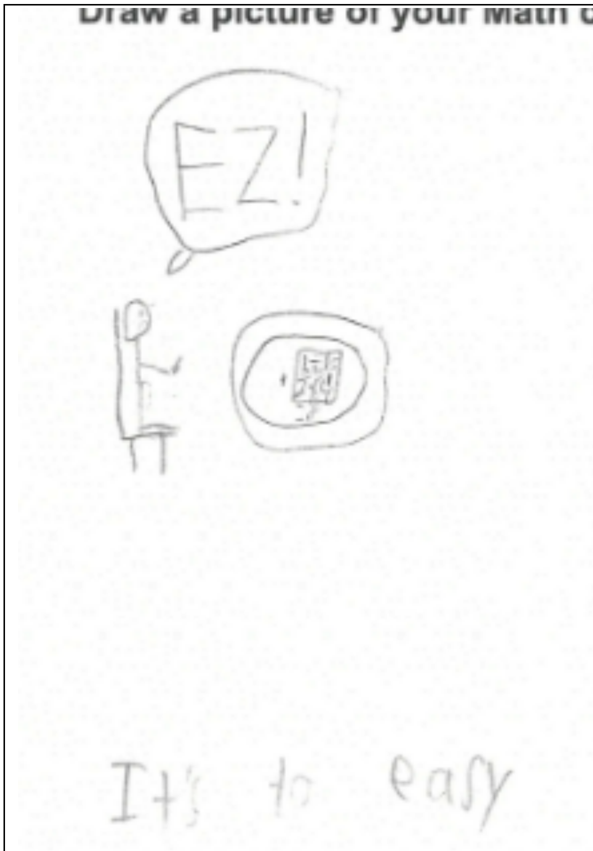
"lame". Jason has said something negative but done so through a happy faced student depiction. This seems to depict an unclear or multifaceted thought on mathematics.



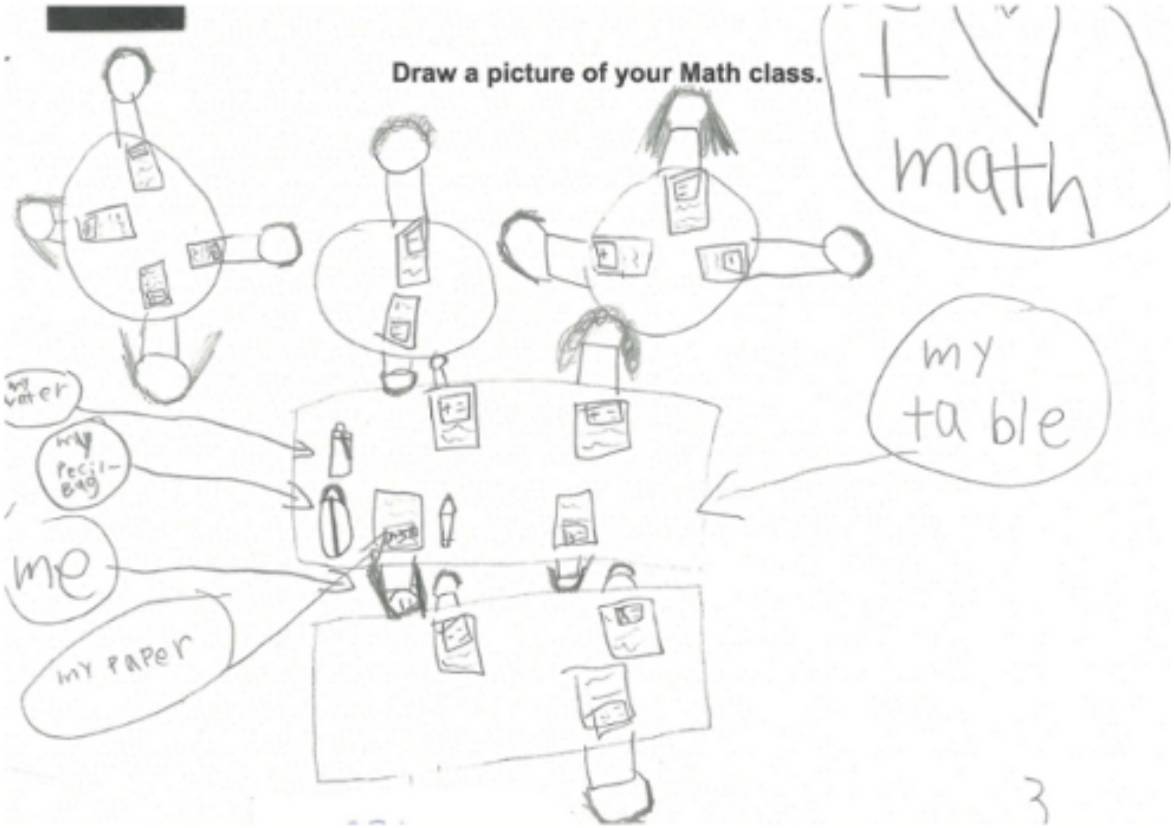
Matilda

Matilda has drawn a row of desks with students sitting at each desk. One student is on a computer, the remaining six are holding pencils up to write. The last student in the row, has their other hand up on their head, resembling a thinking type of position. Two student's faces are hard to discern a mouth represented. Four of them have a straight line for a mouth, having been coded as neutral emotion. One student has a frowning face, this student has some sort of writing above them that was erased well enough to not be able to make out what was written, but with a little residue of the marks. Across the top of the paper Matilda wrote "Math is 4/1 out of 10" This is not a particularly high rating of mathematics, and it also seems to incorporate some idea of fractions.

Sam:
Sam has depicted a student, assumed to be themselves, in the approximate middle of the page alone at a desk. They added color to their chair, clothing and desk. They have long hair, a big eye and a frowning face, with their arms outstretched in front of them. Sam has drawn a speech bubble saying, “So hard!” On the desk is a pencil and a paper with the problem 9x8 written on it. The floor tiles are shown and floating around the desk/student are words. The words are “Satisfying? Hard! Frustrating! Fun?” It is worth noting that the negative emotions are punctuated exclamation marks, and the more positive emotions are punctuated with question marks. This could suggest that Sam questioning if math class is fun and satisfying.

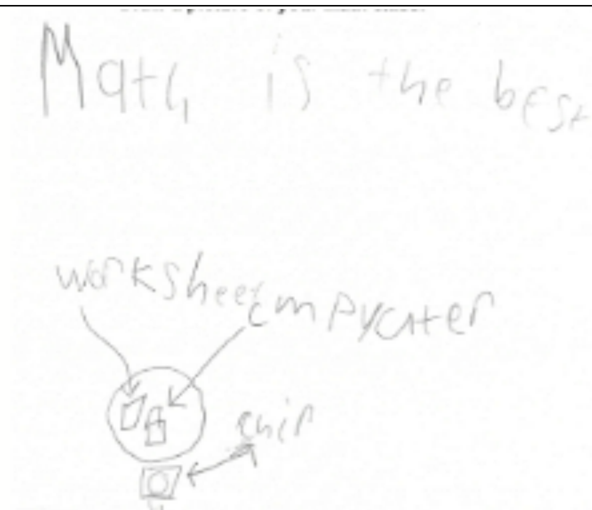


Victoria:
Victoria has shown a student, presumably themselves, with a big frown sitting alone at a desk. There is a paper on the desk with a division and multiplication problem, 1 divided by 6 and 2 x4=8. Above the student is a speech bubble that reads “EZ!” and below the drawing is written “It’s to easy” There is no other student, no teachers or other classroom elements portrayed in the drawing



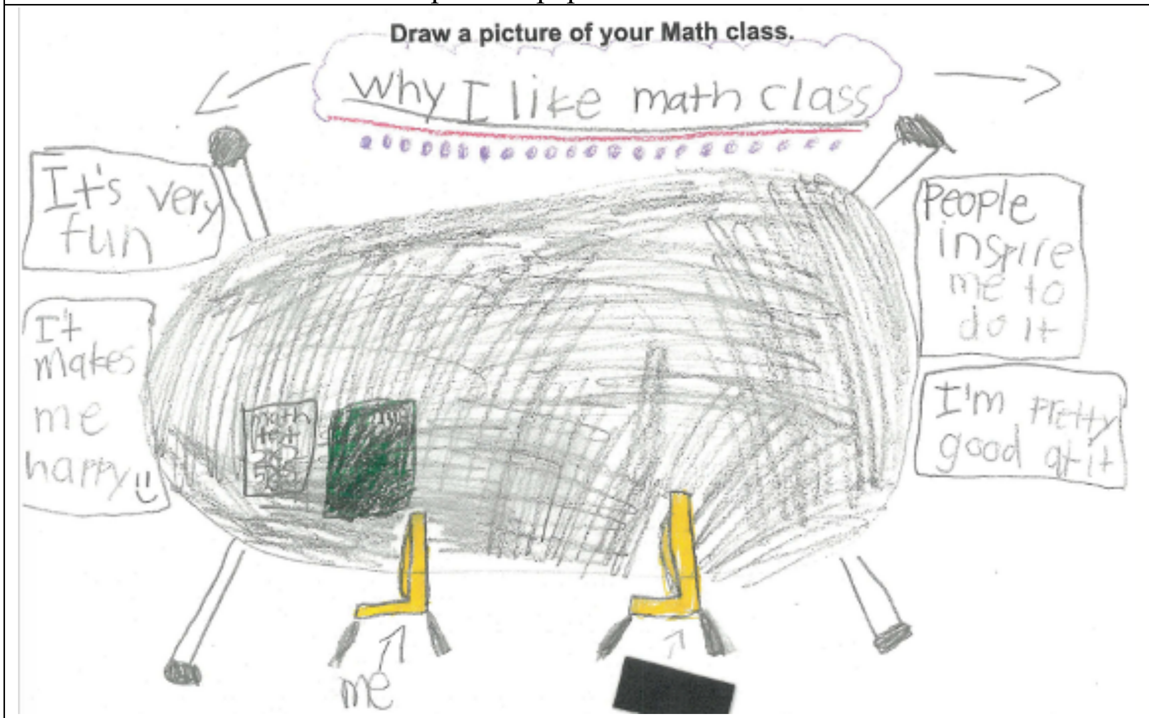
Frankie

Frankie has drawn five tables with 2-4 students at each table. Each student has a paper in front of them with some unreadable scribbles on them. In the upper right corner is the "I (heart drawn) math". Frankie has labeled "my table", "my pencil bag", "my water, "my paper" which are all located in front of the student labeled "me". Frankie is the only student with eyes, but none have mouths or other discernable features."



Hazel

Hazel has drawn a single student sitting at a desk, there are not any other people or items depicted. Hazel has labeled the chair as well as the computer and worksheet that are on the desk in front of the student. On the top of the paper Hazel wrote “Math is the best”

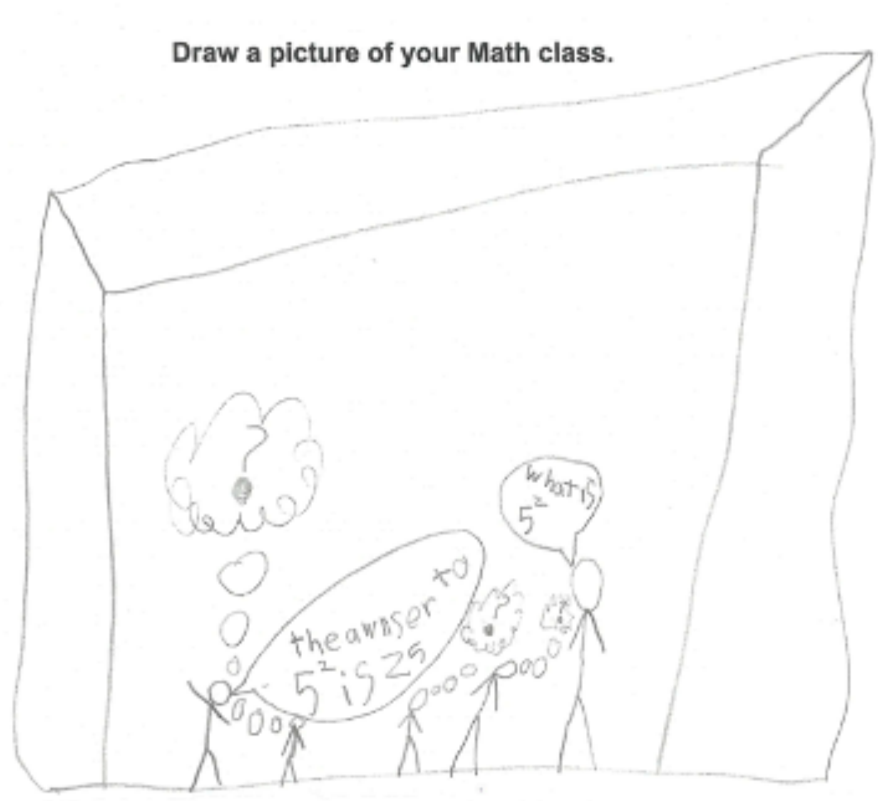


Teddy

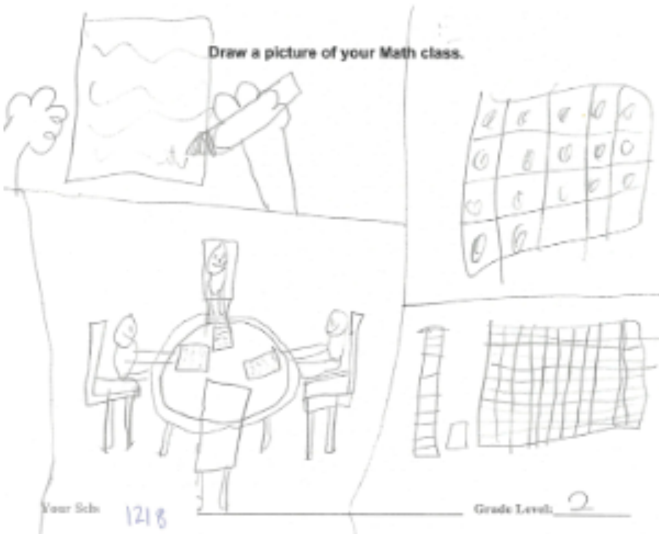
Teddy did not draw students, but labeled the yellow chairs in the drawing, one is labeled “me”. On the table in front of Teddy’s chair is a math test with multiplication and a second paper or book colored green. The top of the image is labeled with “Why I like math class” with an arrow pointing to the right and left off each side of that top banner pointing to reasons that Teddy listed in boxes. The reasons Teddy gave for liking math class were: “It’s very fun”, “It makes me happy =) “, “People inspire me to do it” and lastly “I’m pretty good at it”. Here is one where fun, happiness and success are related to positive feelings about math class. Also, although it is not clear who or what people are inspiring Teddy, there is recognition that inspiration from others has a positive impact on this student’s perception of themselves and their math identity.

Appendix G: Selected Drawings

Drawing that is an example of showing students thinking and/or emotions



These are a sampling of drawings depict multiple activities, and/or multiple stations within the classroom.



Drawing that represents a class of students discussing an answer to a problem, where different students are sharing their ideas and thoughts.

Example of a drawing that depicts the sharing vocabulary and strategies in the math lesson.