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Exploring Students' Emotions and Mathematics Learning in Social Justice Mathematics

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Abstract

In this dissertation, I explored students' expressed emotions as they worked on a problem-solving lab contextualizing the local lead poisoning issue in the city in which they attended college. I identified students' expressed emotions and their reasoning for expressing those emotions. I also looked at the change in students' emotions as they worked through the problem-solving lab, referred to as the lead poisoning lab. In this dissertation, I also analyzed students' self-reports of developing five learning pursuits of Historically Responsive Literacy (HRL) frameworks: identity, criticality, skills, intellect, and joy, and the different ways students developed these learning pursuits. I used Social Justice Mathematics (SJM) and Historically Responsive Literacy (HRL) as conceptual frameworks to guide this study. These frameworks informed the design of the lead poisoning lab. I used HRL learning pursuits to define mathematics learning. This dissertation aimed to answer three research questions: (1) What emotions do college students express in response to learning about local lead poisoning issue and why? (2) How does a lead poisoning mathematics task affect, if at all, college students' emotions as they work through the lead poisoning task in a precalculus class? (3) How did college students self-report their mathematics learning experience after completing a lead poisoning mathematics task designed from a historically responsive literacy lens?

This dissertation is an action research study that is a small part of a much broader action research project. This study reported on data collected from forty-three undergraduate students enrolled in two sections of a precalculus course. For this study, I used the lead poisoning lab developed by the Meaningful Mathematics Research Group led by Dr. Nicole Fonger. I employed a mixed methods approach to analyze data. I used thematic analysis for qualitative

data analysis of students' responses to the lead poisoning task on Desmos and the post-lab Qualtrics survey.

The findings of this study suggested that students experienced various emotions as they worked on a mathematics task embedded in a local injustice issue. Students expressed negative, positive, and self-conscious emotions as they developed an understanding of the lead poisoning issue, learned about the lives of people affected by it, identified the role of people in power, realized the usefulness of lesson content, and analyzed the ongoing efforts to address the lead poisoning issue. I found that students expressed mostly negative emotions after they learned about the lead poisoning issue, but their emotions changed to mostly positive emotions after they learned about the existing efforts to address the lead poisoning issue. The findings also suggested that students developed the five HRL learning pursuits in different ways. The majority of the students agreed that they developed the five HRL learning pursuits in their self-report of their learning.

This study informed the field about students' expressed emotions and the reasons behind their expression. This information could help instructors to anticipate and prepare to address students' emotions in their classroom. This research study provides an example of implementing a social justice mathematics lesson. This research opens up avenues for future research on instructional practices and task designs that address students' emotions in mathematics classrooms.

EXPLORING STUDENTS' EMOTIONS AND MATHEMATICS LEARNING IN SOCIAL JUSTICE MATHEMATICS

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Chapter 1: Introduction

Mathematics education researchers argue that there is a need to change how mathematics is taught in high school (Bartell, 2013; Gonzalez, 2009; Gutierrez, 2002; Gutstein, 2003, 2006; Gutstein & Peterson, 2013) and undergraduate classrooms (see Battey et al., 2022; Guzmán & Craig, 2019; Leyva et al., 2020; Leyva et al., 2021). Gutstein and Peterson (2013) explicitly paid attention to the importance of mathematics as a tool "to help us understand and potentially change the world" (p. 5). Gutstein and Peterson further expressed their concern about mathematics teaching, stating that "math is often taught in ways divorced from the real world" (p. 1). Aligned with this view, Gonzalez (2009) argued that mathematics is a powerful tool to understand the world around us and improve our lives. In addition, Wright (2016) asserted that students perceive mathematics to be relevant when taught through activities based on their social issues.

Mathematizing the contexts of students' lives helps students develop skills that help them understand their lives and environments more clearly (Gutstein & Peterson, 2013). Mathematical activities that focus on issues of inequity in society have been found to increase student engagement in the lesson (Gutstein & Peterson, 2013; Voss & Rickards, 2016). Teaching mathematics by contextualizing students' lives allows students to go beyond their classroom and understand social and environmental issues, as well as carry out investigations about these issues that affect their communities (Gutstein, 2012; Voss & Rickards, 2016). However, students may experience various emotions as they learn about injustices in their community, especially from within their community, as documented by Kokka (2019, 2020).

The research in mathematics education in the past has focused on reasoning (Roth & Walshaw, 2019), and other cognitive factors with very little attention to emotions (Schukajlow et

al., 2017). There is research on understanding mathematics anxiety (Zan et al., 2006) but little research addresses other emotions related to mathematics or experienced in mathematics classrooms (Xu et al., 2024). However, there is an increasing interest in exploring the role of emotions in mathematics classrooms (Kokka, 2019, 2020). Students' emotions play a key role in supporting their mathematical learning (Schukajlow et al., 2017) and, if managed carefully, can be turned into fuel for supporting learning (Zembylas, 2007). Students' emotions of anger, sadness, or empathy may support students' development as active members of the society with ability to use mathematics to understand inequities in society and work toward finding a solution to correct unjust systems (Gutstein, 2006; Kokka, 2019, 2020, 2022; Zembylas, 2007). Recent research suggests that students not only experience emotions when learning about issues of injustice in mathematics classrooms but also bring in emotions from outside the classroom from their interactions with the outside world (Kokka, 2019). In addition, empirical research suggests that not attending to students' emotions results in students' disengagement from the lesson. Battey and colleagues (2022) examined historically marginalized students' responses to discouraging events in undergraduate precalculus and calculus instruction to learn how students process and respond to such events. They concluded that students find it hard to focus on the mathematics lesson when their emotions are not attended to (Battey et al., 2022). The arguments presented here speak to the need of accounting for student emotions as a factor in their mathematics learning process.

Study Aim

The importance of the role of students' emotions in their learning necessitated this research study. There is a need for further research on addressing student emotions in mathematics classrooms (Kokka, 2022). Current literature is insufficient to shed light on the role

of social justice mathematics tasks in supporting students in identifying and expressing their emotions. Gutstein (2003) defined social justice mathematics as mathematics education that is grounded in a vision of social justice that challenges systems of oppression and seeks to promote social change. Social justice mathematics involves using mathematics education as a tool for promoting equity and social change (Gutstein, 2003). This means that mathematics lessons should be designed to help students understand and critique systems of oppression, such as racism, sexism, and economic inequality. Social justice mathematics also involves using real-world, relevant examples to help students see the connections between mathematics and social issues, and to empower them to use mathematics as a tool for social change (Gutstein, 2003).

This research study aimed to explore students' emotions as they work on a social justice mathematics task. The study also aimed to learn about students' self-reported mathematical thinking after working on a social justice mathematics task designed using the historically responsive literacy (Muhammad, 2020, 2023) lens. This research study identified emotions that college students express in the classroom while learning about injustices. This study also explored the reasons behind students' expressions of emotions as they work on the social justice mathematics task. Further, this research study analyzed how the social justice mathematics task affected students' emotions, supported their mathematical learning, and helped students identify and express their emotions. This study shares empirical findings that shed light on students' expressed emotions and their learning of mathematics in social justice mathematics classrooms. In addition, this study focused on the change in students' emotions as they worked on the social justice mathematics task. This research study is part of a broader action research study conducted by the Meaningful Mathematics Research Group led by Dr. Nicole Fonger. For this study, I used a mathematics lesson developed by the Meaningful Mathematics Research Group. The lesson

contextualized the lead poisoning issue in Syracuse, the city where the students attend college. This study provides instructors with a set of student emotions that they might encounter in their social justice mathematics classroom, along with reasons why students expressed those emotions. The findings of this research about student emotions could help instructors prepare their social justice mathematics lessons by incorporating a plan to address potential student emotions. This research study was guided by the following three research questions.

Research Questions

1. What emotions do college students express in response to learning about a local lead poisoning issue and why?
2. How does a lead poisoning mathematics task affect, if at all, college students' emotions as they work through the lead poisoning task in a precalculus class?
3. How did college students self-report their mathematics learning experience after completing a lead poisoning mathematics task designed from a historically responsive literacy lens?

In Chapter 2, I present a literature overview of factors that support students' mathematical learning in social justice mathematics classrooms. In Chapter 3, I discuss the conceptual frameworks that I operationalized in this study. I used a combination of social justice mathematics (Kokka, 2022) and historically responsive literacy (Muhammad, 2020) frameworks for this study. In Chapter 4, I discuss the methods I used to conduct this action research study with undergraduate precalculus students. In Chapter 5, I share the findings from the analyses and answer the research questions. In Chapter 6, I discuss the contributions, implications, and future research lines of inquiry that stem from this research study.

Place-based Education

The geographical place plays an important role in this research study. In our broader research study, we have found that students' sense of belonging to their geographical location results in students' meaningful learning of mathematics. We defined this concept as locality-identity, which refers to "one's sense of belonging to and understanding of a specific geographical area" (Caviness et al., 2023). Other researchers have also highlighted the importance of geographical area in students learning through the concept of place-based education. Vander Ark and colleagues (2020) defined place-based education as education that connects learning to communities and the world around us. Renshaw and Tooth (2018) defined place-based education as an approach that leverages the unique characteristics of specific places to enhance learning. Place-based education involves using the entire community as a classroom and recognizing that place is an integral component of youth development (Vander Ark et al., 2020) by incorporating the physical environment, cultural narratives, and active participation of educators, students, and community members (Renshaw & Tooth, 2018). It emphasizes learning that is deeply connected to the local context, including its material features, historical and cultural meanings, and the agency of the people involved in the educational process (Renshaw & Tooth, 2018; Vander Ark et al., 2020). This approach aims to foster a deeper understanding and appreciation of the environment, encouraging students to engage actively with their surroundings and learn through direct experiences (Renshaw & Tooth, 2018). Vander Ark and colleagues (2020) argued that having students learn by engaging with and within their local communities and places is extremely valuable. Place-based education develops important skills like taking initiative, cultural awareness, and community involvement in students (Vander Ark et al., 2020). Learning is more meaningful when grounded in real-world contexts and environments beyond

the classroom walls. Current educational trends like personalized instruction, skills-based credentialing, immersive technologies, and improved transportation access are creating more opportunities for place-based learning experiences (Vander Ark et al., 2020). Overall, place provides an authentic, engaging setting for students to apply academics while building essential competencies. In this research study, we used the context of a local issue, lead poisoning, to teach students about exponential decay.

Chapter 2: Literature Review

Gutstein and Peterson (2013) argued that mathematical knowledge is essential to developing a deeper understanding of social and political issues. However, the emphasis of mathematics teaching on procedural fluency, memorization of formulas, and application in unknown contexts drives students away from mathematics (Wright, 2016). Wright (2016) argued that mathematics can help students develop an understanding of social justice issues by making an explicit connection between mathematical learning and social justice issues. Justice-oriented mathematics teaching helps students to go beyond their classroom and understand social and environmental issues as well as carry out investigations about these issues that affect their communities (Gutstein, 2012; Voss & Rickards, 2016). Kokka (2022) argued that a justice-oriented mathematics teaching approach helps students develop mathematical skills and skills to question oppressive systems. A justice-oriented mathematics teaching approach teaches mathematics content while questioning the oppressive systems to help students understand and analyze injustices take action (Kokka, 2022). However, the investigation of injustices brings along expressions of emotions. For example, students might display emotions like anger or sadness when learning about injustices in their community, especially if they come from a historically marginalized social group (Kokka, 2022).

Mathematics education researchers have researched, designed, and implemented ways of incorporating social justice mathematics in classrooms for over three decades (see Frankenstein, 1990; Gutstein, 1997, 2003; Tate, 1995). Some researchers discuss the successful implementation of social justice mathematics in classrooms to support student learning (Avcı, 2020; Frankenstein, 1990; Gutstein, 2003, 2007; Kokka, 2019, 2020; Tate, 1995; Wright, 2016) while others shared their struggles (Brantlinger, 2014; Gregson, 2013). In my review of literature

focused on the implementation of social justice mathematics, I found that mathematics education researchers, in their respective studies, have identified five factors that support student learning in a social justice mathematics classroom: co-creating classrooms, using problem-solving and investigative research, social justice mathematics curriculum, attending to students' emotions, and support from school. Table 1 lists the five factors that support student learning in a social justice mathematics classroom with empirical research that supports these factors.

Table 1

Factors That Support Student Learning in Social Justice Mathematics Classroom

Factors	Articles
1. Co-creating classrooms	Brantlinger (2014), Gregson (2013), Gutstein (2003, 2007), Tate (1995), Turner et al. (2009), Voss and Rickards (2016), Wright (2016)
2. Problem solving, group work, and investigative research	Avcı (2020), Frankenstein (1990), Gutstein (2003, 2007), Tate (1995), Wright (2016)
3. Curriculum that supports Social Justice Mathematics	Frankenstein (1990), Gutstein (2003)
4. Attending to students' emotions	Battey et al. (2022), Kokka (2019, 2022)
5. Support from the school	Kokka (2020)

Co-creating Classrooms

The first factor, co-creating classrooms, refers to giving students autonomy and power to be part of classroom decisions. Research in social justice mathematics suggests that sharing authority with students is important in supporting students' learning. Teachers can share their authority with the students in two aspects of running the classroom: creating a comfortable

classroom environment for all students (Gutstein, 2003) and selecting social issues to be studied (Gutstein, 2007; Tate, 1995; Turner et al., 2009; Wright, 2016). Teachers can invite students to build the classroom environment. It could include deciding social norms, guidelines, policies, and classroom setup. The main idea is to create an environment where students feel comfortable sharing their personal experiences and opinions on social and political issues.

In a two-year study of teaching and learning for social justice, Gutstein explored multiple research questions that were later separately published (2003, 2007). In his 2003 exploration, Gutstein identified that co-creating the classroom environment was a primary factor that supported his students' growth. Gutstein (2003) looked at the role of an NCTM-based curriculum in teaching and learning for social justice. Gutstein taught an honors-track seventh-grade class with 26 students. He continued teaching the students in eighth grade when two students left and were replaced by two new students. His students identified as Latinos who were raised by working-class families. He taught the class using real-world projects integrated with a curriculum, Mathematics in Context (MiC). Gutstein analyzed students' sixth, seventh, and eighth grades test scores, high school admission test results, students' journal assignments, practitioner journal entries, students' work on projects, survey responses, and interactions with students using open coding initially and then focused coding. Gutstein (2003) stated that most of his students succeeded in conventional measures of mathematics learning and graduated into college-prep high schools. The author acknowledged that co-creating the classroom with students helped students discuss important issues of equity and gave them a sense of justice. The classroom represented a safe space where students freely engaged in discussions about injustices. Gutstein (2003) asserted that co-creating the classroom helped normalize discussions on taboo topics.

While Gutstein (2003) made a compelling argument in favor of co-creating the classroom as a factor that supported students' growth, the study was conducted in a middle school class with all Latino students. Students belonged to the same marginalized racial group. The results might differ when students come from culturally diverse backgrounds. Additionally, Gutstein (2003) combined real-world projects with MiC while teaching the 7th and 8th grade. The author reported the overall impact of curriculum and projects on students' growth, but the impact of curriculum and projects individually was not determined.

In addition to co-creating the classroom by creating a comfortable classroom environment, teachers can also make students a part of the decision-making process in class. For example, Frankenstein (1983) argued that teachers could ask students about topics and issues they would like to explore. These topics and issues then serve as a starting point for the curriculum (Frankenstein, 1983). Tate (1995), Gutstein (2007), Turner et al. (2009), Voss and Rickards (2016), and Wright (2016) provided empirical evidence to support Frankenstein's (1983) claim.

In his investigation of pedagogical efforts to support the mathematical learning of African American students, Tate (1995) collaborated with a middle school teacher, Sandra Mason, in a predominantly African American school in an urban district. Tate (1995) analyzed Mason's pedagogy and reported that Mason integrated student-raised issues into her instruction which led to students taking action to resolve a community problem. Mason had five years of experience teaching in predominantly African American schools in the same school district. She taught science for three years and was teaching a middle school laureate program at the time of the research study. The laureate program supported students who excel in a particular area but might struggle in others (for example, a student who is good at sports but is unable to read). Mason

constructed the program, based on her philosophical beliefs, as an interdisciplinary approach to community problem-solving. Tate (1995) collected documents related to Mason's pedagogy, including videotapes, newspaper articles, and legislative resolutions. Tate (1995) also collected data by conducting an ethnographic interview with Mason about her pedagogical philosophy and other aspects of teaching, including curriculum, administrative support, and community involvement.

After an in-class inquiry raised and researched by students, Mason and her students successfully convinced the city council to adopt a resolution that liquor not be consumed within 600 feet of schools. This adoption of a resolution speaks to the success of Mason's pedagogy. Tate (1995) analyzed Mason's pedagogy and summed it as a three-step approach: students are asked to identify problems impacting their community, students research and develop strategies to resolve the problem, and students are encouraged to use their developed strategies to resolve the problem. The first step in Mason's pedagogical approach, asking students to identify problems, gives them the autonomy to choose what they will learn. This first step can lead to the development of social agency in students, as seen in Mason's example.

Tate's (1995) study provided an example of how a teacher can help students become aware of their surroundings and use knowledge to learn about and take action to resolve the problem. However, there are two limitations of this study. First, Tate (1995) did not elaborate on the analysis method. As a result, there is no information on how he analyzed the data to describe Mason's three-step pedagogical approach. Second, Mason was not a full-time mathematics teacher; out of her five years of teaching experience, she taught science for three years. Although Mason took an interdisciplinary approach to teaching, it is unclear how this approach could be implemented in a mathematics classroom.

Gutstein (2007) further supported Tate's (1995) empirical findings. The participants, data sources, and method of analysis were the same for Gutstein (2007) as for his earlier study (2003) (described earlier in this section). In this study, Gutstein aimed to investigate conditions that support the development of student agency with 28 Latino students. Developing student agency is a pedagogical goal of social justice mathematics framework (Gutstein, 2006; Kokka, 2022). Gutstein (2007) argued that incorporating the context of students' lives and connecting their mathematical knowledge with their surroundings supported the development of social agency in his students. Gutstein (2007) used qualitative methods to arrive at this conclusion. He conducted this study in a fixed setting where all students belonged to the same racial group and might have a somewhat familiar orientation towards injustice. The results might be different in a culturally diverse classroom. However, this is still evidence that involving students' voices and incorporating their contexts in classroom learning positively influences students' learning.

Turner and colleagues (2009) also provided empirical evidence to support the positive influence of incorporating students' interests in mathematics classroom instruction. Turner et al. (2009) conducted a critical ethnographic study of a math club with twenty students to explore the connections between critical, community, and mathematical knowledge in community-based investigations. The students were all Latina/o from third through sixth grade. The math club members also included four undergraduate facilitators and five participant researchers. The authors collected the data over a two-year period. The data sources included video recordings of all the math club sessions, field notes, classroom observation notes, and interview transcripts of selected students and their parents. Turner and colleagues (2009) employed a grounded theory approach to inform their data analysis. Turner and colleagues (2009) reported that integrating student voice and interest in the classroom provided an entry point into mathematical activity and

created learning opportunities for students to see the relevance of mathematics in the context of their lives.

In a different study, Voss and Rickards (2016) examined the challenges related to teaching mathematics using social justice pedagogies in a ninth-grade classroom. Their study participants included forty-five mixed mathematical abilities students, twenty-eight males and sixteen females, between the ages of thirteen and fifteen. The data sources included observations from researchers' journals, focus group sessions, student work, results of summative assessments, unit concept maps, and student responses to a survey. Voss and Rickards (2016) used a grounded theory approach to analyze the data. This study focused on the challenges of teaching social justice mathematics, but the authors also reported that contextualizing students' interests in mathematics instruction improved student engagement and academic achievement. However, Voss and Rickards (2016) did not elaborate on the connection between integrating student interests and student learning. Instead, they listed it as a practical outcome for teachers as a result of this study.

In another study, Wright (2016) adopted a participatory action research methodology while exploring students' disconnect from mathematics due to the focus on procedural understanding. Wright (2016) formed a research group with five teacher researchers. All the teacher researchers had completed their first year as qualified teachers. Wright had worked with all of them during their teacher education program. The data sources for this study were audio recordings of research group meetings and semi-structured interviews with teacher researchers. Wright (2016) used a thematic approach to data analysis guided by methods from grounded theory. Wright (2016) reported that the teacher researchers stated that encouraging students to choose topics and issues for classroom discussions helped support the development of their

social agency. However, there is no evidence of students' work or thoughts presented (i.e., the claim solely relies on the teacher researchers' self-report of students' experience). It might have added to the strength of this claim if students' voices were captured through an interview with students or classroom observations. This study presented the teachers' side of the story only. One way the present study aims to build on this literature is by centering data from student responses to lessons as evidence of students' self-reported experiences and expression of emotions as they work on the mathematical task.

Research in mathematics education suggests that not integrating student interests in mathematics instruction could result in students' disengagement from the lesson. Brantlinger (2014) reported a similar finding in his exploration of the evolution of discourse in critical mathematics. Frankenstein (1983) defined critical mathematics education as an approach that challenges the dominant ideologies and practices in mathematics that often support societal inequities. The goal in critical mathematics education is to develop students' critical understanding and empower them to take action towards social change. However, critical mathematics emphasizes the critical examination of mathematics and its role in perpetuating societal structures (Frankenstein, 1983), while social justice mathematics focuses on using mathematics to understand and address specific social justice issues (Gutstein, 2006). Brantlinger conducted this study in a remedial geometry class at a night school. There were twenty-eight participants in the study, all between the ages of 18-19 years, with diverse backgrounds. The data sources included detailed transcripts of video-recorded lessons, interviews with students, student work, and exams. Brantlinger (2014) used an adaptation of the qualitative methods framework by Pruyn (1999) to inform his analysis of the data. Brantlinger (2014) found that students were not as engaged in the lesson as he had hoped. He discussed that it could be because he did not

take direct input from the students while constructing the critical mathematics curriculum. Brantlinger's (2014) insights lend support to the idea of integrating student interests and issues students would like to explore, to increase student engagement and learning.

Mathematics education researchers argue that sharing authority with students helps support student learning. However, the teachers need to check how much authority they share. Gregson (2013) reported on the practices of an eighth-grade social justice mathematics teacher, Ms. Myles, who struggled to balance giving students autonomy in classroom decisions and having them work productively. Gregson (2013) examined the practice of Ms. Myles to analyze how Ms. Myles perceived the relationship between mathematics education and social justice and how she enacted this relationship in her mathematics classroom. Gregson (2013) observed more than ninety periods of Ms. Myles's mathematics classroom and some advisory classes. The data sources for this study consisted of observation field notes, class handouts, transcripts of interviews with Ms. Myles, transcripts of a focus group with nine students, and state report cards. Gregson (2013) used qualitative methods to analyze the data starting with preexisting categories and adding new codes. Gregson (2013) reported that Ms. Myles found it challenging to share classroom leadership with students and keep them on task. Students would get into irrelevant arguments or side conversations, making it hard for Ms. Myles to make their time productive. This study sheds light on the importance of co-creating classrooms as productive spaces. This study examined the practice of one teacher and her pedagogy, which limits the generalizability of this study; however, this is still evidence that other teachers might encounter this challenge in their practice. This study does not explicitly identify a factor that supports student learning. Still, I found it important to include this study in the review as it provided insight into how co-creating classrooms could hinder student learning if not mediated.

Problem Solving, Group Work, and Investigative Research

The second factor that supports student learning in a social justice mathematics classroom is using problem-solving approaches, encouraging group work, and promoting investigative research during classroom inquiry. Mathematics education researchers suggest that students' mathematics learning is facilitated when teachers use problem-solving approaches (Frankenstein, 1990; Wright, 2016) and engage students in investigative research (Gutstein, 2003, 2007; Tate, 1995) collaboratively (Avcı, 2020; Tate, 1995; Wright, 2016). I define investigative research as asking questions about the issue, gathering relevant information, questioning the sources, and assessing the authenticity of research findings that help resolve the issue.

In a study with working-class urban adult students, Frankenstein (1990) assessed her critical mathematical literacy curriculum. Frankenstein (1990) defined critical mathematical literacy as the ability to question to develop a deeper understanding of an issue. It also includes using mathematics to create awareness amongst people and enable them to make informed decisions about community structures. Frankenstein (1990) reported that her students initially resisted the critical mathematical literacy curriculum, but gradually, the curriculum helped them realize that they knew more mathematics than they thought. One of the main features of Frankenstein's critical mathematical literacy curriculum was the use of open-ended problem-creating and problem-solving approaches. Frankenstein complemented the problem-solving approaches with a reflective activity where students examined their own and their peers' methods for solving a problem. Frankenstein (1990) seemed to report students' reactions to the critical mathematical literacy curriculum but provided no evidence of the data collected for this study and the methods used to analyze the data. Frankenstein shared her experiences with the students based on her understanding. Even though I agree with Frankenstein that her developed

curriculum could potentially support students in realizing what they know, it would have been a stronger argument if there had been information on data sources and analysis.

Frankenstein's (1990) claim is supported by Tate's (1995) study on pedagogical efforts to support the mathematical learning of African American students (study described in the previous section). Tate (1995) reported that Mason's students convinced the city council to adopt a resolution to move liquor stores away from their school and no liquor consumption within 600 feet of the school. Tate (1995) found that Mason's pedagogy focused on encouraging students to raise questions about issues and brainstorm action plans. Students were encouraged to look for resources that could inform them about the issue and possible solutions. For example, in Mason's class, students researched local laws and regulations that applied to the existence of liquor stores near schools. Their investigation led them to a tax advantage system for liquor stores. Next, students examined a copy of the state beverage code to find violations applied to the liquor store near their school. At every step, students' questions about how to resolve the issue of liquor stores near their school guided their progress. Therefore, Tate (1995) reported that encouraging students to raise questions and supporting them in investigative research was an important factor that supported students to learn, grow, and finally take action. Tate (1995) also stated that Mason encouraged students to work in groups throughout the learning process. Mason complemented investigative research with group work, just as Frankenstein (1990) complemented problem-solving with reflections. As mentioned in the previous section, Tate (1995) does not provide evidence of how the data were analyzed. The argument would have been stronger with a brief discussion of the analysis method. It would have helped other researchers to try and replicate the study in different contexts.

In another study, Avcı (2020) reported that students learned better while working in groups. Avcı (2020) employed participatory action research with thirty-two high school precalculus students to investigate how collaborative learning in social justice mathematics can promote critical citizenship. Avcı (2020) collected data from student journal entries, class discussions, filed notes, and reflective journals. The data were analyzed using versus coding methodology (Saldaña, 2013). Avcı (2020) found that initially, students made groups with peers from similar cultural and ethnic backgrounds, but as they proceeded in the projects, students got into more mixed groups. Avcı (2020) also reported that interacting and studying in groups had a positive influence on students learning. Collaborative work in groups also helped the class come together as a community (Avcı, 2020).

In a different context, Gutstein (2003, 2007) reported the importance of encouraging students to raise questions. In both his studies, analyzing the role of a National Council of Teachers of Mathematics (NCTM)-based curriculum in teaching and learning for social justice (2003) and investigating conditions that support the development of student agency (2007), Gutstein stated the same finding about encouraging students to raise questions rather than have them answer questions. Gutstein claimed that most of his students achieved satisfactory mathematical scores on conventional measures of assessments. I interpret this as the conventional success of Gutstein's pedagogy. Gutstein (2003) said he preferred not to ask his students to answer questions; instead, he preferred for the students to raise questions. Gutstein (2007) argued that raising questions and interrogating sources helps students become critical of the information and see themselves as capable of assessing the accuracy of information. Gutstein (2007) asserted that when students ask questions, they get closer to acquiring new knowledge. These studies by Gutstein (2003, 2007) speak to the importance of encouraging students to raise

questions and investigate sources that align with Frankenstein's (1990) and Tate's (1995) findings. Even though Gutstein's studies were conducted in a fixed setting and might not be generalizable to other settings, there is support from other researchers on the importance of problem-solving and investigative research in supporting student learning which makes it a significant factor. Wright (2016) also reported similar findings about problem-solving approaches and group work in his participatory action research study with five teacher researchers (study described in previous section). Wright (2016) stated that teacher researchers said that using problem-solving approaches to teaching and encouraging students to collaborate in group work supported the development of student agency. However, this study showed only one side of the picture (i.e., it only reported the teachers' perspectives).

Curriculum that Supports Social Justice Mathematics

The third factor that supports student learning of mathematics is a curriculum that promotes the social justice mathematics goals. Gutstein (2006) argued that no curriculum aligned completely with social justice mathematics goals, but teachers could use existing curricula to meet the needs of their social justice classrooms. Frankenstein (1990) developed a critical mathematical literacy curriculum and assessed it with her urban adult students (study described in the previous section). Frankenstein (1990) reported that the curriculum helped her students realize their mathematical power and understanding. Frankenstein's claim speaks to the importance of curriculum in supporting students learning. The curriculum, however, might not wholly align with social justice mathematics goals as defined by Gutstein (2003, 2006) and Kokka (2022) because these goals were formulated well after Frankenstein's (1990) study.

Although Gutstein (2006) pointed out the absence of a social justice mathematics curriculum, they provided an example of a curriculum that could be used to closely align with

social justice mathematics goals in his earlier study. In their 2003 study (described earlier in the paper), Gutstein used Mathematics in Context (MiC) to teach their class along with real-world projects. Gutstein (2003) stated that MiC "raised the level of mathematical sophistication and helped combat the inclination to seek simplistic solutions" (p. 68). Gutstein further reported that curricula like MiC could provide better learning opportunities for working-class students and improve their achievement in mathematics. Gutstein's students were able to come up with their own solution strategies, use multiple perspectives to solve a problem, reason mathematically, build confidence in their mathematical abilities, and communicate their solutions with others. Gutstein (2003) claimed that MiC played a vital role in their students' mathematical growth because it provided multiple perspectives to approach a problem in real-world contexts and asked students to justify their explanations. Gutstein (2003) made an argument for the importance of curriculum in supporting students learning in a social justice mathematics classroom. However, Gutstein integrated the curriculum with real-world projects, and it is unclear how much of the students' growth was due to the curriculum itself or the real-world projects.

Just like Gutstein's (2006) work, the curriculum supported social justice mathematics investigations in this research study. The problem-solving lab was a part of the course curriculum. I will elaborate on the social justice mathematics task in the problem-solving lab later in the methods chapter.

Attending to Students' Emotions

The fourth factor that supports student learning in social justice mathematics classrooms is attending to students' emotions. Attending to students' emotions refers to creating a safe environment for students to display their emotions and using a healing-informed approach

(Kokka, 2019) to address expressed emotions. Kokka (2019) conducted a classroom case study to explore how students analyzed social issues and engaged in healing practices. Kokka selected Ms. Charles's classroom because Ms. Charles, a Black woman, used social justice mathematics in her classroom. Nine middle school students participated in this study. The participants were selected on a first-come, first-served basis. The selected participants were from diverse racial backgrounds. However, racial background was not a factor in choosing the participants. The data sources for this study included observation notes, individual interviews with the teacher and students, task sheets, and student work. Kokka made forty classroom observations over the complete fall term. Kokka used thematic analysis through a constant comparison method to analyze the data. Kokka (2019) reports that the healing-informed practices, for example identification and regulation of emotions, attention to cultural relevance, etc., supported the development of students' sociopolitical consciousness, well-being, and mathematics learning.

Kokka (2022) reinforces the importance of attending to students' emotions to support their learning. Kokka (2022) theorized affective pedagogical goals as the third dimension of social justice mathematics framework. The affective pedagogical goals attend to students changing states of feeling during social justice investigations (Kokka, 2022). Students' emotions do not have to be specific to mathematical content but also include feelings about themselves, their families, their community, relationships, and well-being. Kokka (2022) analyzed the data from her previous studies (2019, 2020) with Ms. Charles and Maggie, respectively. I elaborate on the Kokka (2020) study in the next section. In both these studies, Kokka analyzed the collected data: observation notes, teacher interview transcripts, analytic memos, and social justice mathematics task sheets designed by teachers, using qualitative thematic analysis. The primary purpose of Kokka's (2022) study was to theorize affective pedagogical goals and to

explore how affective pedagogical goals vary in different contexts. After analyzing both classroom case studies, Kokka (2022) reported that implementing the affective pedagogical goals might support other social justice pedagogical goals and facilitate student learning in social justice mathematics classrooms.

Empirical research also suggests that not attending to students' emotions results in students' disengagement from the lesson. Battey and colleagues (2022) examined historically marginalized students' responses to discouraging events in undergraduate precalculus and calculus instruction to learn how students process and respond to such events. The participants included twenty students who self-identified as either a Black woman, Black man, Latina woman, Latino man, or White woman. This study spanned over two semesters with ten different participants each semester. Battey and colleagues collected data through semi-structured interviews with the students and used open and axial coding to analyze the data. Battey and colleagues (2022) reported that when students emotions were not attended to (i.e., students suppressed their emotions), they found it hard to focus on the mathematics content taught in the lesson. This finding highlights the importance of attending to students' emotions in classrooms. This study does not report on a social justice mathematics classroom specifically. Battey and colleagues (2022) provide little information on the instructional materials used in the classrooms. However, I included this study in the review because of the connection it made between students' emotions and their engagement in the lesson. This study helps build a case for attending to student emotions in social justice classrooms such that students' emotions, when not addressed in a regular mathematics classroom, could result in student disengagement. Therefore, attending to students' emotions in a classroom where they learn about injustices is crucial.

Support from the School

The fifth factor that supports student learning is the amount of support that the teacher gets from the school to continue social justice investigations in their classrooms. In her study to investigate how students of privileged backgrounds engage and develop critical consciousness with social justice pedagogy in a mathematics classroom, Kokka (2020) carried out a classroom case study in an elite urban school. Kokka selected the classroom based on the teacher's use of social justice mathematics in their classroom. Similar to Kokka's earlier study (2019), the participants were selected on a first-come, first-served basis. Kokka selected ten participants where four identified as Caucasian, one of European descent, one as White, one as Indian American, and one as Native American. Two participants chose not to respond to that question. The parents of the participants filled out the racial/ethnic background questionnaire. Maggie taught the class, a white woman from a lower socioeconomic status family. The data sources for this study included observation field notes, social justice mathematics task sheets used in class, student work, analytic memos, and interviews with students, teachers, and the school's principal. Kokka used qualitative thematic analysis to analyze observation field notes, student interview transcripts, student work, and analytic memos. Kokka (2020) found that support from school was a primary factor in supporting the development of students' critical consciousness. Kokka (2020) defined critical consciousness as developing students' sociopolitical understanding and taking action (Gutstein, 2006) with critical civic empathy (Mirra, 2018, as cited in Kokka, 2020, p. 782). Critical civic empathy is the ability to put yourself in another person's shoes and look at the world through their perspective to inform decisions about the shared future of society (Mirra, 2018, as cited in Kokka, 2020, p. 782).

Kokka (2020) reported that students' development of critical consciousness was supported by the school's explicit focus on justice learning goals for students and justice-oriented teaching standards for evaluating teachers. The school also allocated funds for Maggie to gain access to social justice mathematics resources, including relevant texts and attending conferences. Furthermore, the school provided Maggie with additional planning time free from the pressure of standardized testing with curricular autonomy. All the supports mentioned played a part in supporting students' development of critical consciousness. Kokka's (2020) study paints a hopeful picture for teachers implementing social justice mathematics in their classrooms. This study was conducted at an elite urban school that likely had the funds to support its teachers financially to attend conferences. Also, the school explicitly focused on social justice learning goals which might not be the case with other schools. This study might be generalizable to other urban elite schools, but the findings might differ for other schools with students not from the same privileged backgrounds.

In this research study, school support included a focus on social justice learning goals and curricular autonomy. The social justice lesson was conducted as a problem-solving lab. The problem-solving lab was a part of the course requirement. The course supervisor emphasized the importance of social justice mathematics and encouraged the instructors to carry out social justice lessons in their classrooms. The problem-solving lab was developed by the course supervisor and her research team with input from the instructors. The instructors had autonomy of how they wanted to conduct the problem-solving lab. The instructors were also part of the discussions about deciding topics for the problem-solving labs.

The current literature in mathematics education provides empirical evidence affirming factors that support student learning in social justice mathematics classrooms. Support for some

factors is well researched and documented (co-creating classrooms, using problem solving and group work, and curriculum) while the other factors are relatively newer to the field (attending to students' emotions) and need more research from the social justice mathematics context (support from school). In the next chapter, I explain the conceptual frameworks for this study that will provide clarity on the research design of instructional activities in this study and why factors that support students' learning in social justice mathematics classrooms are important to this study.

In this literature review, I explored the integration of social justice into mathematics education and highlighted the need for a pedagogical approach that connects mathematical learning with social issues. The literature suggested that traditional mathematics instruction often focuses excessively on procedural fluency, which can alienate students. In contrast, a justice-oriented mathematics approach seeks to make learning more relevant and empowering by addressing social and political issues, thereby fostering students' critical thinking and social awareness. I identified five factors from the literature that support students' learning in social justice mathematics classrooms: co-creating classrooms, problem-solving and investigative research, attending to students' emotions, curriculum that supports SJM, and support from the school. Co-creating classrooms involves sharing classroom authority with students, allowing them to participate in decision-making about classroom norms and topics. This approach is crucial for creating a supportive environment where students feel valued and engaged. Research indicated that such an environment can enhance student learning, although it requires careful management to ensure productivity and focus. Employing problem-solving approaches and encouraging group work and investigative research are critical for engaging students. Studies have shown that these methods help students to understand and apply mathematical concepts in real-world contexts, thereby making learning more meaningful and relevant. This approach also

promotes critical mathematical literacy, empowering students to question and understand societal structures. A curriculum that explicitly incorporates social justice themes can help students see the relevance of mathematics in understanding and addressing societal issues. This type of curriculum encourages students to explore and act on social injustices, thereby linking academic learning with civic engagement. Recognizing and addressing the emotional responses of students is crucial in social justice mathematics education. Emotions such as anger or sadness may arise when students confront injustices, particularly those affecting their communities. Creating a safe space for these emotions and using a healing-informed approach can support students' well-being and engagement. In addition to the discussed four factors, institutional support, including providing resources and curricular autonomy, is essential for the successful implementation of social justice mathematics. Research indicated that schools focusing on justice-oriented learning goals and providing teachers with the necessary support can significantly enhance the effectiveness of this pedagogical approach. Overall, the review underscores the importance of a holistic and inclusive approach to mathematics education that not only focuses on academic achievement but also fosters critical consciousness and social agency among students. The literature suggested that while some factors like co-creating classrooms and problem-solving have been well-researched, others, such as attending to students' emotions and receiving school support, require further exploration to understand their full impact.

Chapter 3: Conceptual Frameworks

For this research study, I used a combination of Kokka's (2022) social justice mathematics (SJM) and Muhammad's (2020, 2023) historically responsive literacy (HRL) frameworks (Fonger et al., in preparation). Both these frameworks guided the development of the lead poisoning problem solving lab in the broader action research study. The frameworks aligned with the research goals of this study and the broader research study. The frameworks focused on teaching in ways to support students to become active members of society by developing socio-political consciousness and using learned knowledge to analyze their environments to play their role in the pursuit of a just society. I elaborate on the fit of the social justice mathematics and historically responsive literacy frameworks later in the chapter after describing each of the frameworks.

The social justice mathematics framework provides a set of pedagogical goals: dominant, critical, and affective. I explain each set of goals later in this chapter. I focused on the affective pedagogical goals for this study. The affective pedagogical goals guided the direction of this research study into exploring students' expressed emotions. I operationalized the second and third affective pedagogical goals in this study. Students were asked to express their emotions during the lead poisoning lab at two points in the lesson. I discuss the design of the lab later in the methods chapter. The critical pedagogical goals of the social justice mathematics framework also align with the goals of the broader research (i.e., focus on teaching mathematics to help students understand and analyze injustices in society and the relations of power and inequities).

Muhammad (2020, 2023) extended culturally relevant pedagogy from Gloria Ladson-Billings' (1995) work by deepening its principles to create a more comprehensive and historically grounded framework. Ladson-Billings (1995) originally articulated culturally relevant pedagogy

with three main components: academic success, cultural competence, and critical consciousness. Ladson-Billings (1995) defined culturally relevant pedagogy as an educational theory and practice that aims to achieve three primary goals: ensuring students' academic success, affirming their cultural identity, and developing their critical consciousness to challenge societal inequities. Culturally relevant pedagogy emphasizes academic achievement, cultural competence, and sociopolitical consciousness, encouraging students to excel academically while valuing their cultural heritage and becoming aware of and addressing social injustices (Ladson-Billings, 1995). This approach is fundamental for promoting educational equity and preparing students to be active and engaged citizens. Muhammad built on these foundations by adding dimensions that address historical context, identity development, and joy in learning. Muhammad (2020, 2023) extended Ladson-Billings' (1995) principles by incorporating a framework that includes identity, skills, intellect, and criticality, which Muhammad refers to as Historically Responsive Literacy. This approach not only aims to make learning relevant to students' lives but also seeks to develop their critical consciousness and empower them to use their education to challenge societal injustices (Muhammad, 2020). Muhammad (2020, 2023) presented five learning pursuits in the historically responsive literacy framework: skills, intellect, identity, criticality, and joy. The historically responsive literacy framework guided in redefining mathematics learning to include the application of mathematical skills in students’ lives in a meaningful way (intellect), the development of socio-political consciousness to analyze injustices using mathematical knowledge (criticality), the expression of emotions in the learning process (joy), and the development of identity as students learn about themselves and people around them (identity) in addition to the acquisition of mathematical skills (skills). The historically responsive literacy

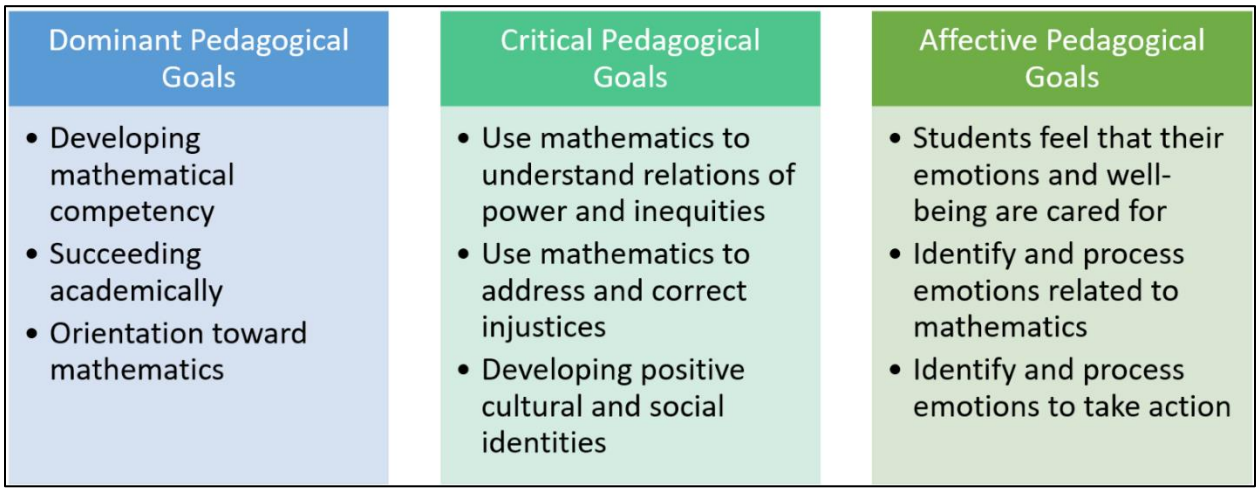
framework also guided the design of the lead poisoning task. We added questions intentionally to elicit students' development of the five learning pursuits.

Social Justice Mathematics

Kokka's (2022) three-dimensional social justice mathematics framework combined Gutstein's (2003, 2006), Gutierrez's (2002), and Kokka's (2015) work and presents a holistic framework that builds up on previous research and adds a new dimension to classroom teaching. For this research study, I used Kokka's (2022) social justice mathematics framework. Kokka (2022) defined the social justice mathematics framework with three sets of pedagogical goals: dominant, critical, and affective. Kokka (2022) listed three goals for each dimension (see figure 1). Figure 1 shows my interpretation of Kokka's (2022) dominant and critical pedagogical goals. I used Kokka's (2022) framing of the affective pedagogical goals in figure 1.

Figure 1

Social Justice Mathematics Pedagogical Goals (Adapted From Kokka, 2022 p. 135)



Dominant Pedagogical Goals

Dominant pedagogical goals include *reading the mathematical word, achieving in the dominant frame,* and *understanding relevance of dominant mathematics* (Kokka, 2022). The

dominant pedagogical goals build upon and align with Gutstein's (2006) mathematics pedagogical goals and Gutierrez's (2002) dominant mathematics. Gutstein (2006) defined *reading the mathematical word* as "developing students' mathematical power" (p. 29). This includes students' knowledge of and ability to use various mathematical methods to explore, conjecture, and solve problems (Kokka, 2022). The second dominant pedagogical goal, *achieving in the dominant frame,* refers to students' success on conventional assessments like standardized tests, and high school and college exams (Gutstein, 2006). The third dominant pedagogical goal, *understanding relevance of dominant mathematics*, aims to support students in viewing mathematics as a powerful tool to understand the world (Gutstein, 2006) rather than rules and formulas to be memorized. Kokka (2022) argued that it includes changing feelings towards dominant mathematics and students' relationship with it.

Critical Pedagogical Goals

Critical pedagogical goals include *reading the world with mathematics*, *writing the world with mathematics*, and *centering marginalized perspectives*. Similar to dominant pedagogical goals, Kokka's (2022) critical pedagogical goals build upon Gutierrez's (2002) critical mathematics and align with Gutstein's (2006) social justice pedagogical goals. Gutstein (2006) defined *reading the world with mathematics* as using mathematics to understand "relations of power, resource inequities, and disparate opportunities between different social groups" (p. 25). Gutstein (2006) defined *writing the world with mathematics* as using mathematics to change the world. He further elaborates it as "a developmental process, of beginning to see oneself capable of making change, and … developing a sense of social agency" (p. 27). The third critical pedagogical goal, *centering marginalized perspectives*, refers to highlighting the experiences and perspectives of students from marginalized groups, acknowledging that some students might

come from a privileged background, and helping all students develop positive cultural and social identities.

Affective Pedagogical Goals

Teaching mathematics through social justice could have emotional and traumatizing effects on students, and teachers must be prepared to respond to student affect (Kokka, 2022). This is where affective pedagogical goals come into play. The three affective pedagogical goals are "for students to feel that their emotions and well-being are cared for by centering relationships and healing", "to identify and process emotions related to dominant mathematics", and "to identify and process emotions to take action" (Kokka, 2022). The first affective pedagogical goal, "for students to feel that their emotions are cared for by prioritizing relationships and healing" in the classroom, refers to teachers attending to student emotions and creating a comfortable environment for students where they feel safe displaying emotions (Kokka, 2022) knowing that their emotions will not be suppressed. The second affective pedagogical goal, "to identify and process emotions related to dominant 890-=mathematics", recognizes students' emotions towards mathematics as an important part of their learning. Students can gain confidence and use their emotions to learn dominant mathematics by identifying and processing emotions pertaining to mathematics (Kokka, 2022). The third affective pedagogical goal, "to identify and process emotions to take action," refers to supporting students' learning by helping them to identify their emotions as they learn about injustices in society and process emotions to develop social agency (Kokka, 2022).

Historically Responsive Literacy

I used Muhammad's (2020, 2023) historically responsive literacy framework to define student learning of mathematics in social justice classrooms and understand students' emotions in

their written responses for this study. Muhammad (2020, 2023) defined the historically responsive literacy (HRL) framework with five learning pursuits: *identity*, *skills*, *intellect*, *criticality*, and *joy*. I briefly describe all five learning pursuits below.

Identity

Identity is defined as a person's belief about themself, their future self, and their perception of others' view of them (Muhammad, 2020). A person's identity is fluid and continuously reshaped by their sociopolitical and sociocultural environments. Examples may include a person's personal, racial, gender, and community identities. Students should be able to see themselves in their learning. In this study, social justice mathematics provided students with an opportunity to learn about themselves, their environments, and others in their environments by contextualizing community problems in mathematics classrooms.

Skills

Muhammad (2020) defined skills as "proficiencies measured using quantitative, high-stakes assessments" (p. 85). Skills focus on student learning outlined by the standards set by the states or school districts. Muhammad (2020) argued that teaching skills is important, but skills should be taught along with the other learning pursuits. In a mathematics classroom, skills include students' ability to explore the problem, reason logically, provide evidence for their mathematical arguments, justify their solutions, in addition to learning about various mathematical concepts and methods.

Intellect

Intellect is defined as "the understanding, enhancement, and exercising of mental powers and capacities that allow one to better understand and critique the world" (Muhammad, 2020, p.

104). Intellect also includes the application of learning in ways connected to the real world. Muhammad (2020) argued that students can expand mental capacities and express ideas through their solutions to world problems. Social justice mathematics provides students opportunities to develop intellect by applying their mathematical learning to solve social problems from their communities.

Criticality

Muhammad (2020) defined criticality as the ability to "see, name, and interrogate the world not only to make sense of injustice but also to work toward social transformation" (p. 120). Criticality includes understanding of power relations, systems of oppressions, and inequities in society (Muhammad, 2020). Social justice mathematics aims to develop the same traits in students through mathematizing inequities in society, supporting students to use mathematics as a tool to understand injustices, and develop social agency to correct injustices.

Joy

Muhammad (2023) defined joy as students' feeling of happiness and celebration in learning. The concept of joy also includes feelings healing, wellness, and justice (Muhammad, 2023) as students engage with social justice contexts. For this study, I broadened the learning pursuit of joy to include all emotions that students experience and express in a mathematics classroom as they work on the lead poisoning task.

The social justice mathematics task was developed around issues of injustice to equip students with an understanding of inequity and the tools to correct injustices. The five learning pursuits of the HRL framework supported the modification of the task in the broader action research project (Caviness et al., 2023; Fonger et al., 2023; Fonger et al., in preparation). The five learning pursuits align with Kokka's (2022) social justice mathematics pedagogical goals.

The learning pursuits of identity, intellect, and criticality support the social justice pedagogical goals. The learning pursuits of skills and joy support mathematics and affective pedagogical goals, respectively. I used these five learning pursuits to examine student responses for evidence of holistic learning in social justice mathematics classrooms.

For this research study, I followed Fonger and colleagues (in preparation) in defining mathematical learning with the five learning pursuits from Muhammad's (2020, 2023) HRL framework. Student learning is a combination of learning mathematical skills (skills), applying mathematical skills in their life to understand their environments (intellect), developing awareness of themselves and the people around them (identity) while understanding the existing power dynamics in society (criticality), and expressing emotions as they learn about injustices and use mathematics to understand inequity in society (joy).

I employed a combination of the two conceptual frameworks for this research study: Kokka's social justice mathematics (SJM) framework and Muhammad's historically responsive literacy (HRL) framework. The SJM framework combines insights from previous research by Gutstein and Gutierrez and introduces a holistic approach to teaching mathematics with a focus on social justice. It comprises three sets of pedagogical goals: dominant, critical, and affective. Dominant goals include reading the mathematical word, achieving in the dominant frame (success on conventional assessments), and understanding the relevance of dominant mathematics as a tool for understanding the world. Critical goals emphasize using mathematics to understand power relations and resource inequities, as well as to enact change in the world. Affective goals focus on the emotional aspects of learning, encouraging students to express their feelings and experiences in relation to social justice contexts. Muhammad's historically responsive literacy (HRL) framework builds on culturally relevant pedagogy and emphasizes

five learning pursuits: identity, skills, intellect, criticality, and joy. Identity focuses on students' beliefs about themselves and their cultural backgrounds. Skills refers to the proficiencies measured by assessments, emphasizing the importance of teaching skills alongside other learning pursuits. Intellect involves enhancing mental capacities to understand and critique the world. Criticality encourages students to interrogate societal injustices and develop a sense of social agency. Joy highlights the emotional aspects of learning, promoting happiness and celebration in the educational process. I used these frameworks together to create a learning environment that not only teaches mathematical skills but also fosters critical consciousness, emotional engagement, and a sense of identity among students, empowering them to address social injustices in their communities.

Chapter 4: Methods

In this chapter, I discuss the methods I used to accomplish my goals for this study. I used a mixed-methods, qualitative and quantitative methods research design (Morse, 2010) to guide this research study. I conducted a three-phased data analysis approach (discussed later in this chapter). The first two phases of data analysis focused on qualitative analysis. I conducted thematic analysis (Braun & Clarke, 2006) in phase 2. In the third phase, I carried out quantitative analysis, including descriptive statistics. This research study is part of a bigger ongoing action research study led by Dr. Nicole Fonger. I conducted an action research study to identify student emotions and their development of HRL learning pursuits as they work on the lead poisoning lab. I focused on one cycle of the larger research study.

Action Research

Lewin (1946) described action research as a three-step process of planning, executing, and fact finding (as cited by Baumgart, 2022). The first step involves careful planning of the research idea, followed by the second step of executing the plan. The third step focuses on evaluating the first two steps by gaining insights from the execution of the plan and assessing the necessary modifications required to improve the educational outcomes (Baumgart, 2022). Action research supports teachers to reflect on and investigate their practices with the aim of improving students' outcomes (Baumgart, 2022; Erbilgin, 2019; Samuelsson, 2023). Action research is grounded in the needs of the practitioners, which makes it an effective tool for educational research (Erbilgin, 2019).

In this research, I aimed to understand student emotions when learning about injustices in the classroom so I, as a practitioner, can support my students' learning by helping them resolve their emotions. Action research methodology was a good fit for this research study as it allowed

me and the other instructors to reflect on our execution of the task and learn about the necessary adjustments to the lesson for the next time we teach. It also helped us improve our students' education by understanding the process of change and generating new knowledge of students' emotions and the different ways they develop the HRL learning pursuits.

The Broader Action Research Project

The broader action research project led by Dr. Nicole Fonger and our research team had completed four cycles of teaching social justice mathematics lessons to undergraduate students by the end of spring 2023. Dr. Fonger's research team includes local high school teachers, graduate students, undergraduate students, and high school students. This research project is focused on developing lessons on local social justice issues and teaching these lessons in an undergraduate classroom at a predominantly white university. In the broader action research project, we have conducted four iterations of a social justice lesson on highway 81. We introduced the lead poisoning lab in the fourth iteration of the action research project. The highway 81 lab focused on the social justice issue of destroying a thriving African American and Jewish neighborhood to build an interstate highway in the 1950s. The construction of the highway resulted in the displacement of a predominantly African American and Jewish community who had lived in the 15th ward. The highway 81 lab also highlights the issue of redlining. In the lead poisoning lesson, we focus on the social and environmental justice issue of lead poisoning in houses and make connections between the prices of the houses and lead poisoning levels in the neighborhood. Data Warriors is a group of high school students led by Mr. Keech, a local high school mathematics teacher. Mr. Keech co-creates the classroom with his students and encourages students to share issues that they face in their communities. Data Warriors identify the local social and environmental justice issues that they want to learn about

and that matter to them. Then, the research team mathematizes the identified issues and creates lessons to be taught at the high school as well as the undergraduate level.

In our qualitative analyses of students' responses from the highway 81 lab, we found strong evidence of emotions embedded in students' responses. This evidence necessitated the need to explore students' emotions as they work on social justice mathematical tasks. In the lead poisoning lab, we added questions asking students to express and explain their emotions.

Settings and Participants

I conducted this study at a predominantly white institution in the northeastern United States. All the participants were enrolled in a precalculus course. I used a task developed by the Meaningful Mathematics Research Group (MMRG) led by Dr. Nicole Fonger and a team consisting of mathematics teachers, as well as graduate and undergraduate student researchers. Dr. Nicole Fonger, Ken Keech, Stephen Caviness, Karley Voyias, and I developed the lead poisoning task. The instructors taught the lead poisoning task (see figure 2 for the lead poisoning lab) as a part of students' regular course instruction. Problem-solving labs are integrated into the precalculus course instruction as a required course activity. The lead poisoning task was one of two problem-solving labs participants completed in one semester. The lead poisoning lab was taught in a 120-minute class period. The lead poisoning lab was the second problem-solving lab of the semester. Students had already completed a social justice lab earlier in the semester focused on highway construction and its impact on the Syracuse city population. The lead poisoning lab had a similar structure to the first problem-solving lab. I will discuss the structure of the lead poisoning lab later in this section. I recognize that students' responses to some questions on the lead poisoning lab might be influenced by their work on the first problem-solving lab.

The participants of this study are forty-three college students enrolled in two sections of precalculus. One section had twenty-four enrolled students, while the other had nineteen. The participants came from different racial backgrounds, with a few identifying as multi-racial. Table 2 shows information about students' self-identified racial demographics. One student out of the forty-three preferred not to disclose information about their racial background.

Table 2

Students' Self-identified Racial Demographics

Self-identified Race	Frequency
White	23
Native American	4
Black/African American	5
Hispanic	4
Asian	2
Mixed race	3
West African	1
Preferred not to disclose	1
Total	43

In designing this study, I predicted that the findings of this research with a racially diverse group of participants would highlight the expressed emotions of students from different backgrounds and might help strengthen the generalizability of the findings to other diverse groups. Kokka (2020) argued that there is a need to include students of all backgrounds in the discussion of social justice mathematics. The diversity of my participants helped me analyze the

diversity of emotions felt by students from different backgrounds based on their lived experiences.

Research Design

Two different instructors taught the lead poisoning social justice mathematics task to their respective precalculus sections. I aimed to develop a theory about different ways students develop HRL learning pursuits as part of their mathematical learning and the different emotions students express in a mathematics classroom. One of the goals of action research is to improve educational outcomes (Baumgart, 2022). This action research study will help me improve students' educational outcomes by identifying students' expressed emotions and the effect on their expressed emotions as they work through the lead poisoning lab while measuring students' mathematical learning through Muhammad's (2020) HRL framework. The problem-solving labs aim to help students develop an awareness of inequities in society and a sense of social agency (Gutstein, 2006) and learn to apply mathematics concepts to understand the world around them. In the broader action research project, we made design decisions specifically to elicit students' holistic understanding of mathematical concepts building on Muhammad's (2020) model. For example, we added a mapping activity to the highway 81 lab to help students make connections with the place and develop identity. We also added a mapping activity in the lead poisoning lab to help students make a connection between housing prices and lead levels. In the previous cycles of the broader action research, we focused more on developing identity, criticality, intellect, and skills, but in the first iteration of the lead poisoning lab, we felt the need to incorporate students' emotions in the study. We hypothesized that students would display a range of emotions as they learn about injustices, and we wanted to learn about it. In this research we wanted to identify what emotions students express and why, and how they develop identity,

criticality, skills, intellect, and emotion. For this research study, we specifically added emotion cards to help students express their emotions. As suggested by the literature, student emotions can play a role in supporting their learning (Kokka, 2019, 2022) and keeping them engaged in the lesson (Battey et al., 2022). We added emotion cards at two intervals in the lesson. Students were asked to express their emotions after they learned about the lead poisoning issue in Syracuse. This was intended to capture students' emotions as they learn about injustice. We hypothesized that the students would display emotions like sadness, helplessness, etc. as they learned about the environmental injustice in their community. We added the emotion card again toward the end of the lesson after students learned about ongoing measures to mitigate the lead poisoning problem in Syracuse. We hypothesized that the students would express positive emotions like relief, hopefulness, etc. as they learned about existing efforts and solutions to address lead poisoning.

Instructional activities

I used the lead poisoning lab developed by Dr. Fonger and our research team as the second problem-solving lab for the precalculus course. The lab consisted of three activities: a pre-lab survey, the lead poisoning task, and a post-lab survey. The pre- and post-lab surveys were designed and conducted using Qualtrics. The lead poisoning task was developed on Desmos. Desmos is an online platform to create and conduct lessons in the form of slides (Desmos.com). The Desmos slides can be considered survey pages where students submit their responses with an addition of interactive tools (e.g., interactive graphs, equation builder, audio and visual files) that the students can use to learn more about the context of the problem or mathematical concepts. Students have the flexibility of going back and forth on the Desmos

slides. Students completed the lead poisoning task and recorded their responses online on Desmos. Each activity is discussed in turn next.

Pre-lab Survey. Students were assigned four resources related to lead poisoning before the lab to help them understand the context of the lab. These resources were embedded in the Qualtrics survey. The resources included Onondaga County Lead Poisoning Prevention Program (Onondaga County Health Department, n.d.), LeadSafeCNY article on how children get lead poisoning (LeadSafeCNY, n.d.), lead pollution interactive charts (Ritchie & Roser, 2022), and an article on lead in human body (Agency for Toxic Substances and Disease Registry, n.d.). Students were asked to respond to questions about their sense of belonging to Syracuse, their understanding of lead poisoning and its effects after exploring the four resources, and their perspective on how mathematics could be used to help rectify the environmental justice issue (see Table 3 for the complete pre-lab survey). These questions were followed by two mathematics questions on exponential function graphs to assess their prior knowledge and understanding of functions, specifically exponential functions.

Table 3

Pre-lab Survey Questions

Pre-lab Survey
1. Who is your instructor?
2. What is your first and last name?
3. What are the last 4 digits of your SUID?
4. How, if at all, has your sense of belonging to Syracuse changed since lab 1?
5. Explore three of the four sources below. Make sure to open these links in a new tab so you don't lose your progress!

a. Onondaga Health Department

b. Lead Safe CNY

c. Our World in Data - Lead Pollution

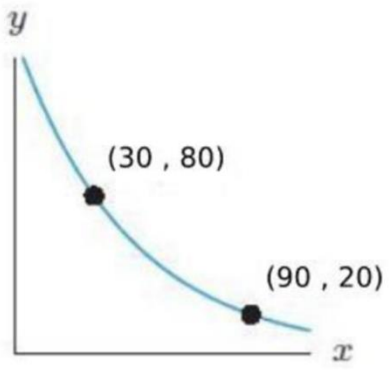
d. What is the biological fate of lead in the body?

Based on the sources above, what is lead poisoning?

6. How does one get lead poisoning?
7. What are some of the effects of lead poisoning?
8. Why does lead poisoning matter?
9. How do you think mathematics can be used to help with lead poisoning? Or environmental justice in general?
10. Will the graphs of the two functions cross in the first quadrant? Explain.

$$f(x) = 18(1.15)^x \; ; g(x) = 13(0.85)^x$$

11. Find a formula for the exponential function shown below.



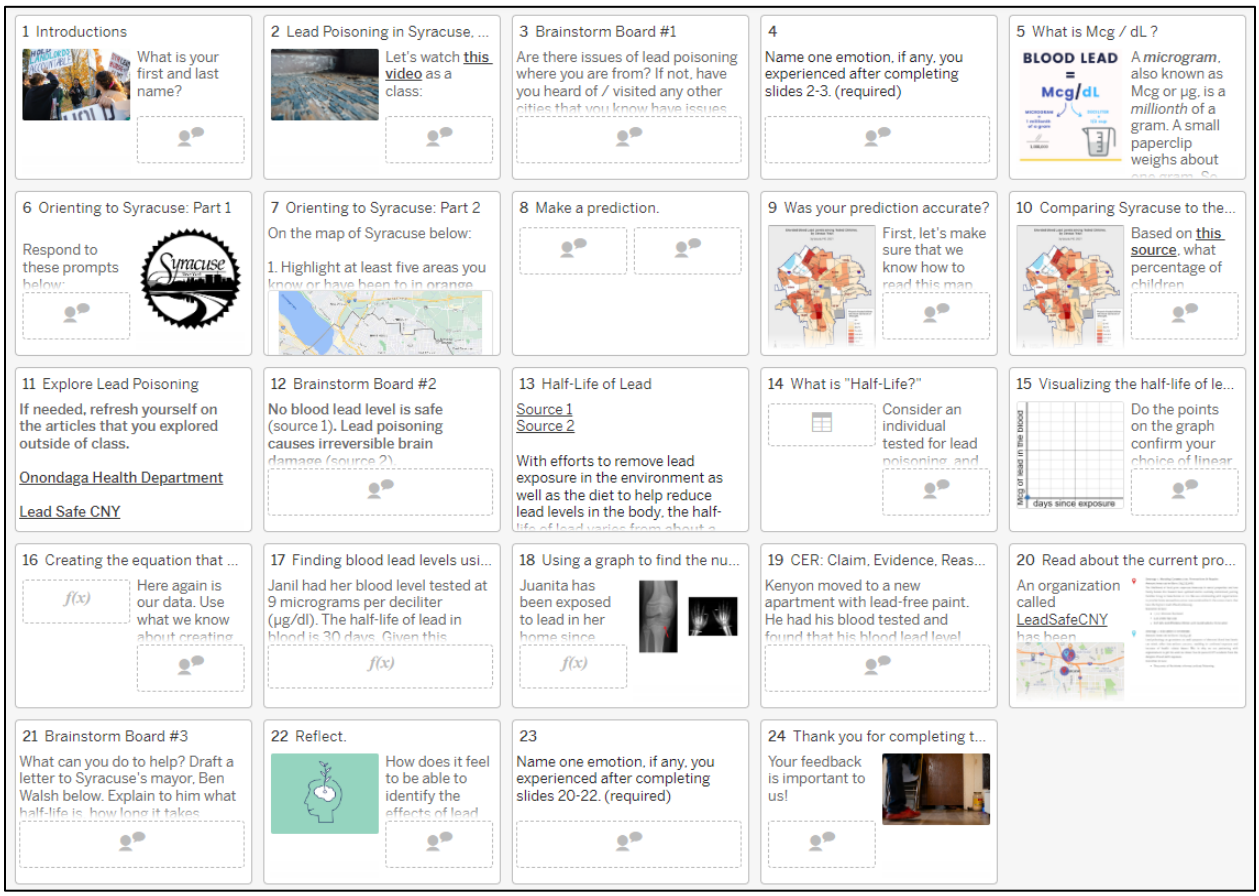
Lead Poisoning Task. During the lead poisoning task, students learned how the lead poisoning context was mathematized and learned the mathematical content on exponential decay. The lead poisoning task helped students understand, use, and interpret exponential functions. The

lead poisoning task also included questions asking students to identify their emotions after learning about the social injustice issue. These questions were placed in the task at specific intervals to help students record their emotions at a given instance in the lesson.

Students attempted the lead poisoning task in class by signing into Desmos using the access code provided by the instructors. The lead poisoning task comprised of twenty-four slides with questions and/or information related to the lead poisoning issue on each slide. Figure 2 shows all the twenty-four slides from the lead poisoning task.

Figure 2

Lead Poisoning Task



Note. The complete lead poisoning task on Desmos can be accessed using the link https://teacher.desmos.com/activitybuilder/custom/642349e34fa651b3a7e09ad0.

Students added information about their social identity, including name and race, on the first slide. The whole class watched a YouTube video (New York Civil Liberties Union, 2019) together on the second slide, and then students wrote about what stood out to them and what they wanted to know more about. On slide three, students were asked if their home city/town has a lead poisoning issue or if they have been to a place with lead poisoning issue. Slides one to three aimed to highlight the effects of injustice and help students place themselves in the context of the injustice issue. On slide 4, students were asked to identify up to three emotions that they felt after learning about the lead poisoning issue and explain why they felt those emotions.

Slides five to twelve focused on placing students in the broader Syracuse area by asking them to highlight areas that they have been to or know about on the map of Syracuse. Students were further shown two maps of Syracuse: housing prices map, and lead levels map. Students were asked to make a connection between housing prices and lead levels in Syracuse. Slide twelve oriented students to think about approaches to mitigate lead poisoning. Slides thirteen to nineteen focused on developing mathematical skills. These slides showed how the lead levels in a human body could be modeled using exponential functions. Students plotted given lead levels on a graph to determine the shape and nature of the curve that best fits the points. Students worked on a few exponential function problems on these slides. Slides 20-21 shared information about efforts to mitigate the lead poisoning issue in Syracuse and asked students to draft a letter to the Mayor of the city explaining the importance of reduced blood lead levels and how to achieve those levels. Slides 22-23 reoriented the students toward their emotions. Students responded to questions asking about their feelings after knowing the effects of blood lead levels and ongoing efforts to mitigate lead poisoning. Slide 23 specifically asked students to list and

explain up to three emotions that they felt. The last slide invited students to give feedback on the lead poisoning task.

Post-lab survey. Students completed the post-lab survey after the lead poisoning task. The research team intentionally designed the survey to elicit students' development of the five tenets of Muhammad's (2020) HRL framework. The post-lab survey asked students if they found the problem-solving lab meaningful and why (see Table 4 for complete post-lab survey). The survey invited students to share their perspectives on the usefulness of mathematics in understanding and addressing issues of injustice. Students responded to 5-point Likert scale questions, rating their experience in the problem-solving lab as relevant to their life experiences and learning in the mathematics classroom. The post-lab survey also included 5-point Likert scale questions where students rated the problem-solving lab in helping them develop mathematical skills, identity, intellect, criticality, and emotion.

Table 4

Post-lab Survey Questions

Post-lab Survey
1. Who is your instructor?
2. What are the last four digits of your SUID?
3. Did you find the problem-solving lab to be meaningful to you? (Yes/No)
4. Explain your previous answer.
5. How, if at all, has your perspective changed regarding the usefulness/ meaningfulness of mathematics in addressing or understanding environmental justice issues within the Syracuse community?

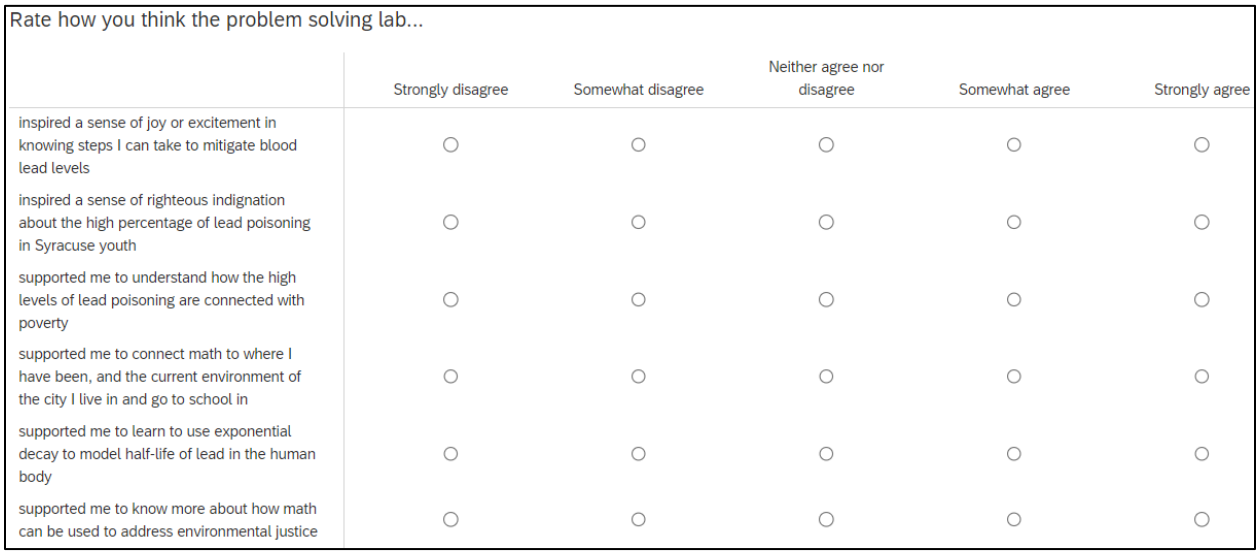
6. Think about your overall experience completing the Problem-Solving Lab as part of MAT 194 in Spring 2023. Rate the following. (5-point Likert scale question)
    a. The Problem-Solving Lab is relevant to my life experiences.
    b. The Problem-Solving Lab is relevant to what I learn in math class.
7. Rate how you think the problem-solving lab... (5-point Likert scale question)
    a. Inspired a sense of joy or excitement in knowing steps I can take to mitigate blood lead levels
    b. Inspired a sense of righteous indignation about the high percentage of lead poisoning in Syracuse youth
    c. Supported me to understand how the high levels of lead poisoning are connected with poverty
    d. Supported me to connect math to where I have been, and the current environment of the city I live in and go to school in
    e. Supported me to learn to use exponential decay to model half-life of lead in the human body
    f. Supported me to know more about how math can be used to address environmental justice
8. Rate how the lab helped you…(5-point Likert scale question)
    a. Experience different emotions
    b. Learn something about real-world events
    c. Practice mathematical skills
    d. Apply mathematical knowledge to a real world situation
    e. Learn about yourself and others in your community

9. Is there anything else you'd like to tell us about your experience completing the Problem-Solving Lab and its relevance to you?

Figure 3 shows question 7 and Figure 4 shows question 8 from the post-lab survey as examples of 5-point Likert scale questions with the five options students could choose from for their responses.

Figure 3

Post-lab Survey Likert Scale Question 7

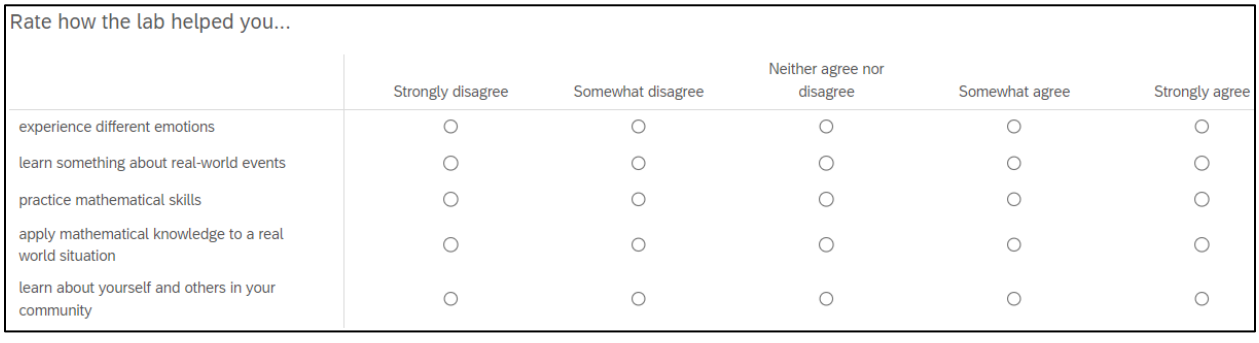


Rate how you think the problem solving lab...

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
inspired a sense of joy or excitement in knowing steps I can take to mitigate blood lead levels	○	○	○	○	○
inspired a sense of righteous indignation about the high percentage of lead poisoning in Syracuse youth	○	○	○	○	○
supported me to understand how the high levels of lead poisoning are connected with poverty	○	○	○	○	○
supported me to connect math to where I have been, and the current environment of the city I live in and go to school in	○	○	○	○	○
supported me to learn to use exponential decay to model half-life of lead in the human body	○	○	○	○	○
supported me to know more about how math can be used to address environmental justice	○	○	○	○	○

Figure 4

Post-lab Survey Likert Scale Question 8



Rate how the lab helped you...

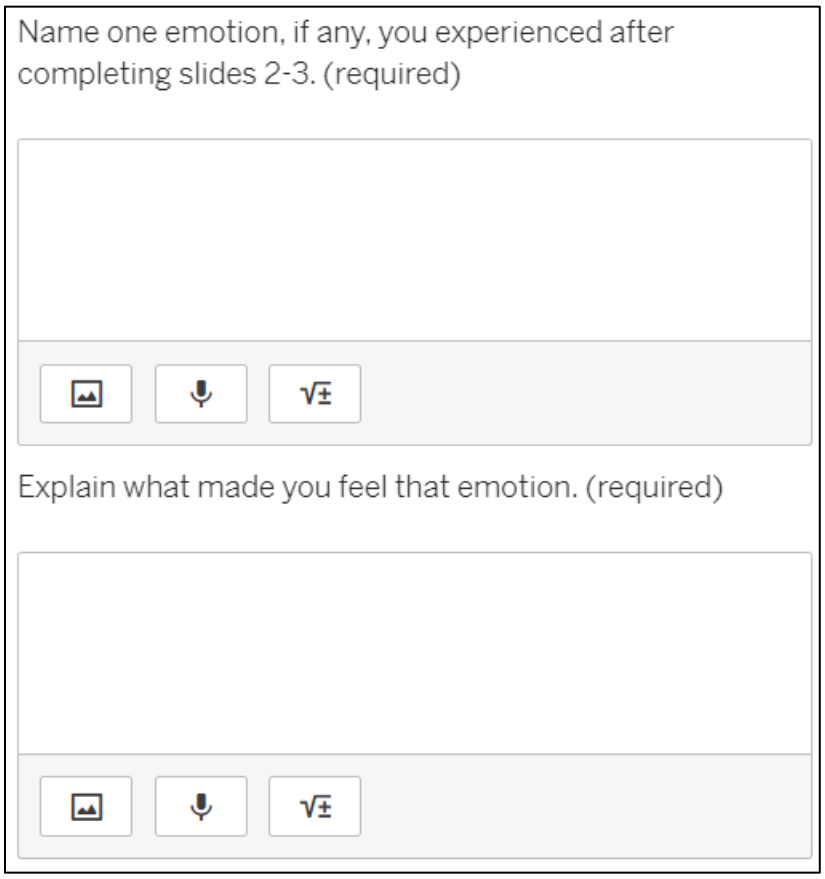
	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
experience different emotions	○	○	○	○	○
learn something about real-world events	○	○	○	○	○
practice mathematical skills	○	○	○	○	○
apply mathematical knowledge to a real world situation	○	○	○	○	○
learn about yourself and others in your community	○	○	○	○	○

Lead Poisoning Lab Design

These slides were designed intentionally for students to express their emotions about the lead poisoning issue. Slides 4 and 23 are identical (see Figure 5). Each slide provided a space for students to list up to three emotions that they felt at two different intervals during the lead poisoning task. Students were also asked to explain why they felt the certain emotion that they expressed. Slide 4 assessed students' emotions and reasoning for emotions right after they watched the lead poisoning video and learned about the lead poisoning issue. Students' responses to slide 23 provided insight into their expressed emotions and reasoning for those emotions after they learned about the efforts to mitigate lead poisoning in Syracuse.

Figure 5

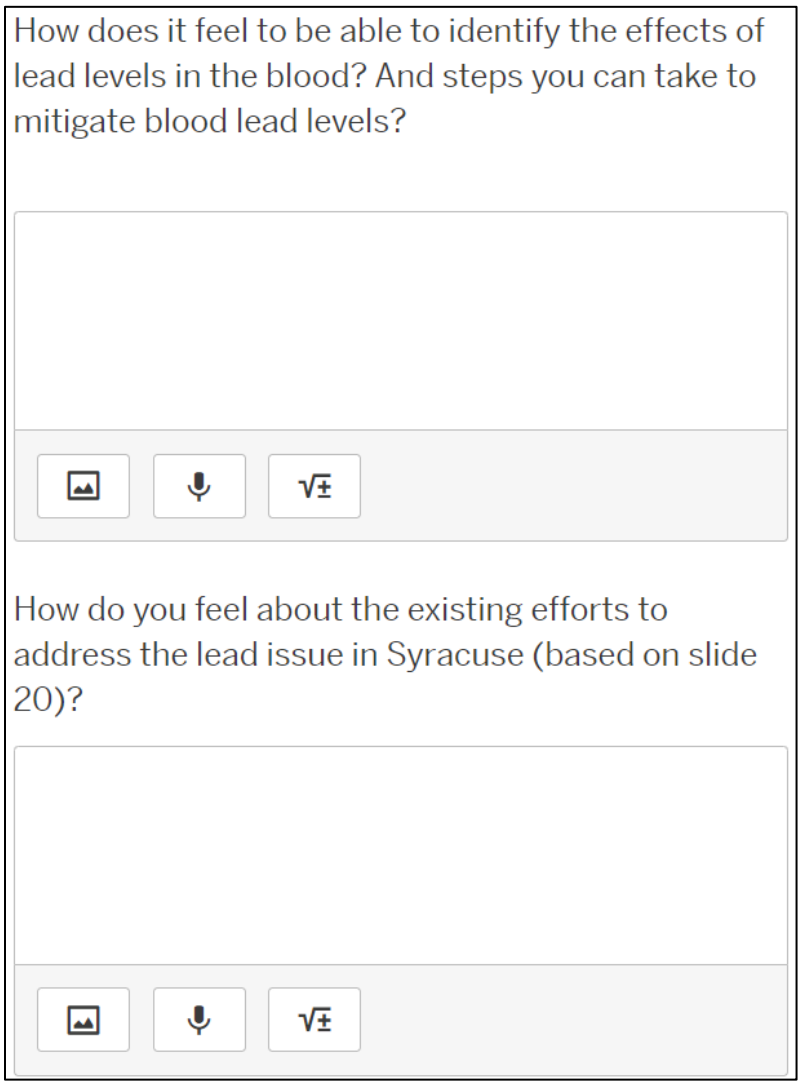
Questions on Slides 4 and 23 of the Lead Poisoning Task



Similarly, slide 22 invited students to share their feelings as they learned about the effects of lead levels in blood and efforts to address the lead poisoning issue (see Figure 6).

Figure 6

Questions on Slide 22 of the Lead Poisoning Task



We also intentionally designed slides for the lead poisoning task to focus on the other four HRL learning pursuits: identity, criticality, intellect, and skills. Similar to the lead poisoning task, we designed questions for the post-lab survey to help us understand students' self-reporting of the five HRL learning pursuits. For example, question 7 parts (b) and (c), and question 8 part

(b) were intentionally worded to support students' development of criticality. Tables 5-9 show lists of designed questions on the lead poisoning task and the post-lab survey for each of the five HRL learning pursuits. These questions then served as the data sources to measure each of the five HRL learning pursuits in our data analysis. We predicted that the designed questions would help us measure their respective learning pursuits.

Table 5

Designed Questions to Measure Identity

Data Source	Questions
Lead poisoning task	Slide 3. Are there issues of lead poisoning where you are from? If not, have you heard of / visited any other cities that you know have issues with lead poisoning? Slide 6. Are you originally from Syracuse? If not, where are you from? In what ways do you feel connected with (or disconnected with) Syracuse? Slide 21. What can you do to help? Draft a letter to Syracuse's mayor, Ben Walsh below. Explain to him what half-life is, how long it takes blood-lead levels to decrease in someone's body, and any related reasons why blood lead levels in Syracuse, NY need to be reduced. Which of the five strategies mentioned in the previous slide do you think should be prioritized?
Post-lab survey	Q8. (e) Rate how the lab helped you... - learn about yourself and others in your community.

Table 6

Designed Questions to Measure Criticality

Data Source	Questions

Lead poisoning task	Slide 2. After watching this video, what are you interested in knowing more about? What stood out as important? Are you familiar with the issue of lead poisoning? Slide 21. What can you do to help? Draft a letter to Syracuse's mayor, Ben Walsh below. Explain to him what half-life is, how long it takes blood-lead levels to decrease in someone's body, and any related reasons why blood lead levels in Syracuse, NY need to be reduced. Which of the five strategies mentioned in the previous slide do you think should be prioritized? Slide 22. How does it feel to be able to identify the effects of lead levels in the blood? And steps you can take to mitigate blood lead levels? How do you feel about the existing efforts to address the lead issue in Syracuse (based on slide 19)?
Post-lab survey	Q7. (b) Rate how you think the problem-solving lab... - inspired a sense of righteous indignation about the high percentage of lead poisoning in Syracuse youth. Q7. (c) Rate how you think the problem-solving lab... - supported me to understand how the high levels of lead poisoning are connected with poverty. Q8. (b) Rate how the lab helped you... - learn something about real-world events.

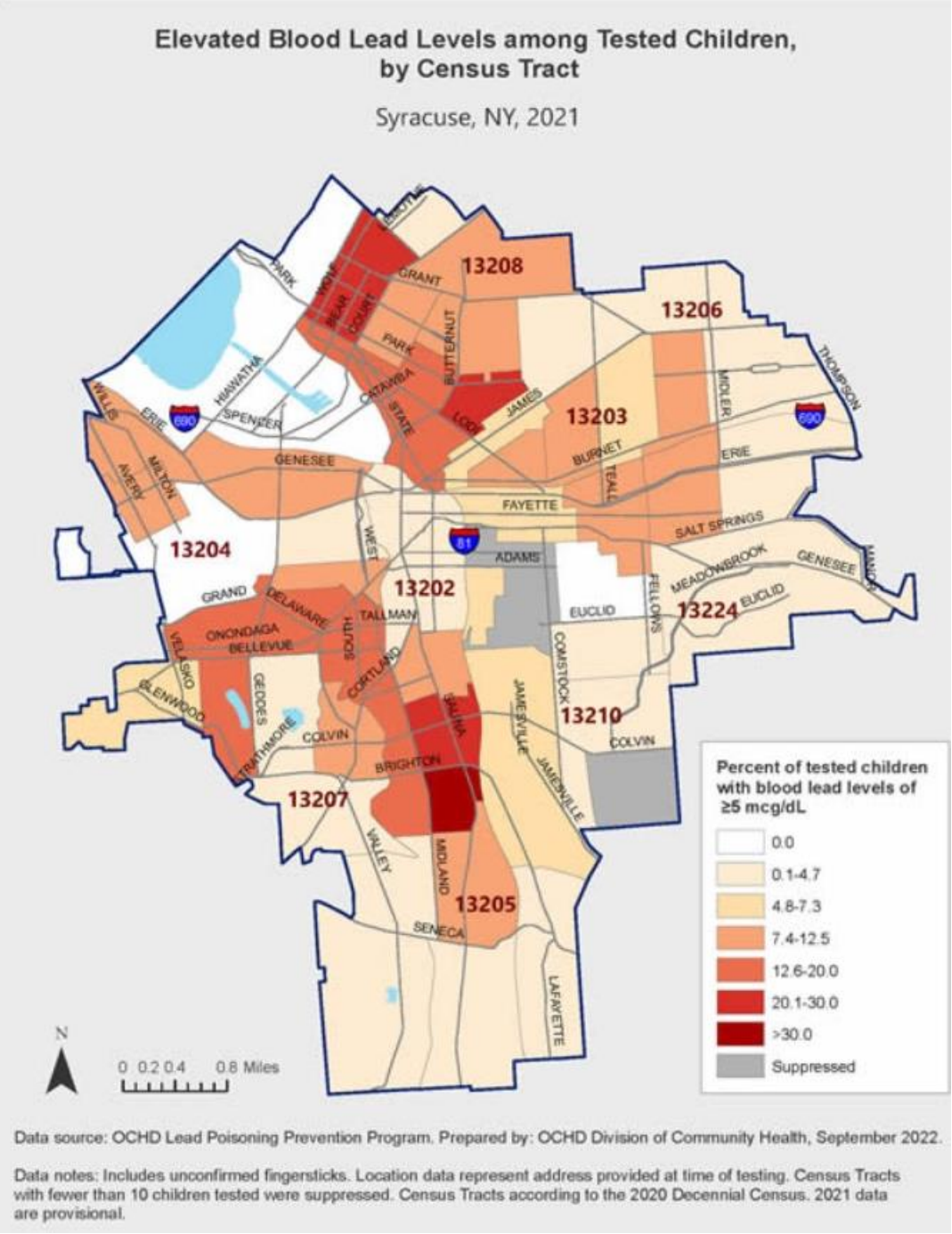
Table 7

Designed Questions to Measure Skills

Data Source	Questions

Lead poisoning task

Slide 9. If you lived in the 13205 zip code, what percent of tested children have blood lead levels greater than 5 µg/dL?



Slide 10. Based on this source, what percentage of children nationwide have blood-lead levels greater than or equal to 5 µg/dL? How does this compare with

	someone who lives at the intersection of Brighton and Midland based on this map of Syracuse? Slide 14. Complete the table that relates days since exposure and blood lead level for 370 days, or about one year. Note that Desmos has a calculator built in, meaning you can type in 6/2 instead of 3. Examine the table once you have filled it in. Is this data showing linear or exponential decay? Explain. Slide 15. Do the points on the graph confirm your choice of linear or exponential? Explain. Slide 16. Create the equation that matches our data. Slide 17. Janil had her blood level tested at 9 micrograms per deciliter (µg/dl). The half-life of lead in blood is 30 days. Given this information, write a mathematical model relating time (measured in days) and blood levels. Assume that Janil had no exposure to lead after getting her blood tested. Write the exponential decay function for this scenario below. Using your mathematical model above, find Janil's blood lead level after 5 days. (Use the calculator button at the top of the page to find this answer). How about her blood lead level after 40 days? Slide 18. Juanita has been exposed to lead in her home since birth. Unfortunately, the constant exposure has allowed 20 µg of lead into her bones. The half-life of lead in bones is 25 years. Input the function for this scenario below and then answer the questions.
Post-lab survey	Q7. (e) Rate how you think the problem-solving lab... - supported me to learn to use exponential decay to model half-life of lead in the human body. Q8. (c) Rate how the lab helped you... - practice mathematical skills.

Table 8

Designed Questions to Measure Intellect

Data Source	Questions
Lead poisoning task	Slide 8. Make a prediction about property prices and lead-poisoning areas. Slide 17. Janil had her blood level tested at 9 micrograms per deciliter (µg/dl). The half-life of lead in blood is 30 days. Given this information, write a mathematical model relating time (measured in days) and blood levels. Assume that Janil had no exposure to lead after getting her blood tested. Write the exponential decay function for this scenario below. Using your mathematical model above, find Janil's blood lead level after 5 days. (Use the calculator button at the top of the page to find this answer). How about her blood lead level after 40 days? Slide 18. Juanita has been exposed to lead in her home since birth. Unfortunately, the constant exposure has allowed 20 µg of lead into her bones. The half-life of lead in bones is 25 years. Input the function for this scenario below and then answer the questions. If Juanita stops exposing herself to lead, how long will it take for the lead levels in her bones to go down to 5 µg? Explain how you found this answer. Slide19. Kenyon moved to a new apartment with lead-free paint. He had his blood tested and found that his blood lead level was 14 µg/dL. He claims that his blood lead level will drop down to 3.5 µg/dL in 6 weeks. Evaluate his claim. Do you agree with Kenyon? Why or why not?

Post-lab survey	Q7. (d) Rate how you think the problem-solving lab... - supported me to connect math to where I have been, and the current environment of the city I live in and go to school in. Q7. (f) Rate how you think the problem-solving lab... - supported me to know more about how math can be used to address environmental justice. Q8. (d) Rate how the lab helped you... - apply mathematical knowledge to a real-world situation.

Table 9

Designed Questions to Measure Emotion

Data Source	Questions
Lead poisoning task	Slide 4. Name one emotion, if any, you experienced after completing slides 2-3. Explain what made you feel that emotion. Slide 22. How does it feel to be able to identify the effects of lead levels in the blood? And steps you can take to mitigate blood lead levels? How do you feel about the existing efforts to address the lead issue in Syracuse (based on slide 19)? Slide 23. Name one emotion, if any, you experienced after completing slides 20-22. Explain what made you feel that emotion.
Post-lab survey	Q7. (a) Rate how you think the problem-solving lab... - inspired a sense of joy or excitement in knowing steps I can take to mitigate blood lead levels. Q8. (a) Rate how the lab helped you... - experience different emotions.

Data Collection

The data sources for this study include forty-three students' responses to the lead poisoning task submitted on Desmos and forty-one students' responses to the post-lab survey responses to the Likert scale and open-ended questions (Bogdan & Biklen, 2007). Two students from one section of the precalculus class did not complete the post-lab survey. Students submitted their responses to the lead poisoning task on Desmos and pre- and post-lab surveys on Qualtrics. In this section, I discuss the data that I used to answer the three research questions of this study. I did not analyze data from the pre-lab survey as it did not provide insights into answering the research questions for this study. The first two research questions focused on students' expressed emotions and their explanation for expressing those emotions, and the change, if any, in their expressed emotions from the beginning to the end of the lead poisoning task. The third research question focused on students' self-reports of developing the five HRL learning pursuits after completing the lead poisoning task on Desmos. Considering these goals of the research study, I chose not to analyze data from the pre-lab survey.

To answer the first research question, I qualitatively analyzed student responses to slides 4, 22, and 23 of the lead poisoning task. The second research question focused my analysis on examining whether students' expressed emotions changed as they learned about lead poisoning and efforts to address it. I compared students' responses to slide 4 with their responses to slides 22 and 23 to assess whether their expressed emotions had changed at all. I hypothesized that there would be a change in students' expressed emotions. For the third research question, I measured each of Muhammad's (2022) HRL framework's five learning pursuits individually to analyze whether the students developed the five HRL learning pursuits. Tables 5-9 show questions and their respective data sources that I analyzed to measure identity, criticality, skills,

intellect, and emotion, respectively. The qualitative analysis of the lead poisoning task informed me about different ways that students developed the HRL learning pursuits. The qualitative analysis provided evidence of students' development of the HRL learning pursuits to support quantitative findings of students' self-reported development of the learning pursuits.

Data Storage

I anonymized students' responses to the Desmos lead poisoning task, saved them as a Desmos dashboard, and downloaded as a Microsoft Word file. Similarly, I anonymized students' responses to the post-lab Qualtrics survey and downloaded them as a Microsoft Excel file. I saved all the data files in a secured folder on One Drive, accessible only to the research team members.

Data Analysis

I analyzed student responses to the lead poisoning task and post-lab Qualtrics survey in three phases using qualitative and quantitative analysis methods. In the first phase, I read students' responses to identify questions from the lead poisoning task and post-lab survey that could help me answer my research questions. In the second phase, I employed an inductive coding approach by conducting thematic analysis (Braun & Clarke, 2006) of students' written responses to open-ended questions with a member of the research team, Emanuel Boutros. I used inductive coding because of its flexibility and potential to directly uncover patterns from the data. I wanted to understand students' explanations of their expressed emotions and different ways in which students develop the five HRL learning pursuits. The inductive coding approach supported my goals for this study. Phase 2 began in the first week of December 2023. In the third phase, I focused on quantitative analysis of students' responses to Likert scale questions on the post-lab survey. I conducted the quantitative analysis with another member of the research team,

Hanyi Xu. Phase 3 started in the third week of January 2024. Emanuel and Hanyi were both active members of the research team and were enrolled in undergraduate programs at Syracuse University. They both had qualitative and quantitative analysis experience in the previous cycle of the broader action research project (Boutros et al., 2023). They were both familiar with qualitative and quantitative analysis software that we used, MAXQDA and Microsoft Excel.

Phase 1

I immersed myself in the data in the first phase to identify questions from the lead poisoning task and the post-lab survey that could potentially help respond to the three research questions. I used Tables 5-9 as a guide to help identify data sources but also looked for evidence of students' emotions and learning pursuits across students' responses to the lead poisoning task and post-lab survey questions.

Phase 2

In phase 2, I immersed myself in the data with Emanuel for qualitative analysis of students' responses to open-ended questions from the lead poisoning task and post-lab survey identified in phase 1. We analyzed forty-three students' responses to the lead poisoning task. Emanuel and I started qualitative coding with the emotion Desmos slides (Table 9) and then Desmos slides from Tables 5-8. We completed the qualitative coding process by the end of February 2024. Emanuel and I followed Braun and Clarke's (2006) six-phased thematic analysis. The flexibility and adaptability of thematic analysis to different research contexts make it a good method for analyzing student responses to open-ended questions. My aim was to paint a complete picture from the data without any preconceived ideas. This approach helped me understand student responses better compared to approaching the data with pre-set themes. Furthermore, the broad applicability of thematic analysis makes it a suitable method to explore

the research questions of this study. Braun and Clarke (2006) present a six-phased thematic analysis approach that facilitates identifying patterns within the data and describing the data in detail. I have listed the six phases of thematic analysis below.

1. Familiarizing yourself with the data
2. Generating initial codes
3. Searching for themes
4. Reviewing themes
5. Defining and naming themes
6. Producing the report

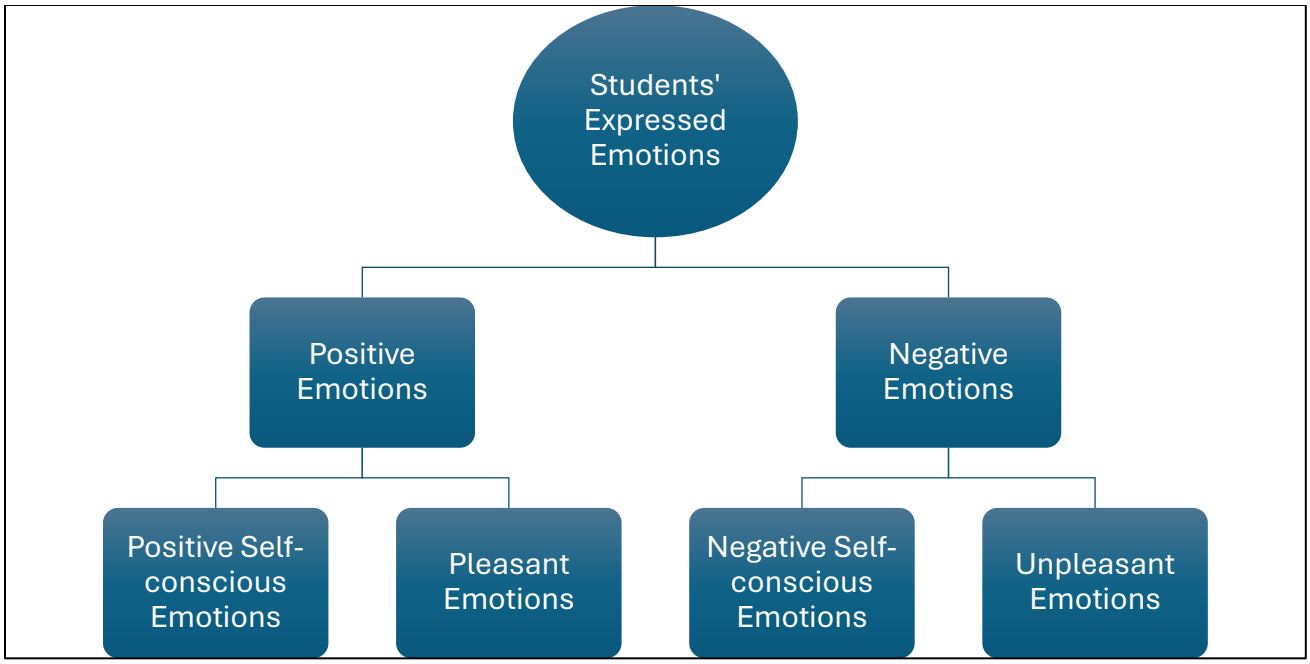
The six phases can be followed in the order listed, but we jumped between the phases as we went back and forth in the data during analysis. For example, while reviewing themes in phase 4, we jumped back to phase 1 and looked at the identified data excerpts to ensure the fit of themes with the data. This jumping back and forth ensured our analysis was rigorous and the themes were carefully identified and defined to answer the research questions. The thematic analysis helped us identify major recurring themes in the data. We then matched the emerging themes from students' responses with Muhammad's (2020) HRL framework to analyze evidence of students' development of identity, skills, intellect, criticality, and emotion. We matched the themes with the HRL framework to identify different ways the students developed the HRL learning pursuits. We employed Braun and Clarke's (2006) thematic analysis first to understand the data and approach data with a clear mind to interpret students' responses without any prior framework in mind. We tried to minimize any effect of knowledge of Muhammad's (2020) HRL framework on the analysis. However, I recognize that the HRL framework might have some influence during the thematic analysis. I minimized the influence of HRL framework by

analyzing the data with another researcher without informing the researcher about my identification of the questions to potentially answer the three research questions. This helped me look at the data through the other researcher's perspective and keep the influence of HRL to a minimum.

In phase 2, I also classified students' expressed emotions into different categories. I used the theory of positive and negative emotions (Gu et al., 2019) to divide students' expressed emotions into two categories. Gu et al. defined negative and positive emotions based on their levels of pleasure. Negative emotions, such as fear and anger, typically have a displeasure component, while positive emotions, such as joy and happiness, usually have a pleasure component, encouraging approach and engagement behaviors (Gu et al., 2019). After classifying emotions into negative and positive, I further categorized students' expressed emotions into two sub-categories for each main category. I split negative emotions into unpleasant and negative self-conscious emotions and positive emotions into pleasant and positive self-conscious emotions. My further classification of negative and positive emotions into unpleasant, pleasant, and self-conscious emotions was guided by students' explanations of their expressed emotions. Figure 7 shows the classification of emotions into categories.

Figure 7

Raja's Further Classification of Emotions Using Gu et al.'s (2019) Theory of Negative and Positive Emotions



Phase 3

In phase 3, I worked with Hanyi on quantitatively analyzing the post-lab survey responses. We applied quantitative methods to analyze forty-one students' responses to Likert scale survey questions to determine students' self-assessment of the development of identity, criticality, skills, intellect, and emotion. We started with descriptive statistics for each of the five learning pursuits. We created pie charts and stacked column bar charts from the post-lab survey responses. I also created pie charts for different categories of students' expressed emotions. We started the quantitative analysis in the third week of January 2024 and completed it by the end of February 2024.

Chapter 5: Findings

In this chapter, I discuss the findings from the qualitative and quantitative analyses of students' responses to the lead poisoning task and post-lab survey. I respond to each research question separately in their respective sections and then present a summary of the overall findings of the study before the discussion section. Recall the research questions for this study:

1. What emotions do college students express in response to learning about local lead poisoning issue and why?
2. How does a lead poisoning mathematics task affect, if at all, college students' emotions as they work through the lead poisoning task in a precalculus class?
3. How did college students self-report their mathematics learning experience after completing a lead poisoning mathematics task designed from a historically responsive literacy lens?

The findings of the first research question inform the findings of the second research question. In answering the first research question, I identified different emotions that students expressed and provided explanations for. I identified themes for students' explanations of feeling expressed emotions. These findings of students' expressed emotions and their reasoning inform the second research question that focused on the change in students' expressed emotions after learning about the lead poisoning issue and the ongoing efforts to address the issue. The findings of the third research question highlight students self-reporting of development of the HRL learning pursuits. The themes identified in the findings of the first research question also inform the findings of the third research question as ways students develop the HRL learning pursuits.

RQ1: What emotions do college students express in response to learning about local lead poisoning issue and why?

In my qualitative analysis of students' submitted responses to the lead poisoning task on Desmos slides 4, 22, and 23, I found that the students expressed a total of 60 different emotions. Students stated these emotions in their written responses to slides 4, 22, and 23 of the lead poisoning task (see Figures 5 and 6). Slide 4 asked students to express their emotions and reasoning right after they learned about the social justice issue on slide 3. Slides 22 and 23 asked students to express their emotions after they learned about the ongoing efforts to mitigate the lead poisoning issue in Syracuse on slide 20. Table 10 lists all the emotions that students expressed arranged alphabetically. It is important to note that the contents of Table 10 are emotions identified by the students, and I am reporting their written words here.

Table 10

Students' Expressed Emotions

Accomplished	Devastated	Guilt	Pity
Anger	Disappointed	Happy	Positivity
Annoyance	Disbelief	Heartbroken	Relief
Anxiety	Disgust	Helplessness	Sadness
Calm	Disturbed	Hopeful	Safe
Comfortable	Educated	Horrible	Satisfied
Compassion	Empathy	Indifferent	Scared
Compelling	Empowering	Informed	Shock
Concern	Enlightened	Interested	Surprised
Confident	Excited	Intrigued	Sympathy

Confused	Fear	Knowledgeable	Uncomfortable
Content	Feel good	Motivated	Unpleasant
Critical	Frightened	Nervousness	Unsettled
Curiosity	Frustration	Optimistic	Upset
Despair	Grateful	Peaceful	Worrisome

I further categorized the 60 emotions using the theory of positive and negative emotions (Gu et al., 2019). I classified the 60 emotions expressed by students into two broader categories: positive (thirty emotions) and negative (thirty emotions). I further classified the emotions in each category into two further categories. I split negative emotions into unpleasant (eighteen emotions) and self-conscious (twelve emotions) emotions, and positive emotions into pleasant (seventeen emotions) and self-conscious (thirteen emotions) emotions. Students' explanations for their expressed emotions drove this further classification of negative and positive emotions. Negative self-conscious emotions included negative emotions where students' explanations hinted toward their self-awareness of their privilege of not knowing about the lead poisoning issue or lack of experience dealing with it. For example, a student expressed shock and wrote "I was unaware that lead poisoning was still a thing and lead poisoning itself is a very dangerous thing to still have around." In this response the student acknowledged their lack of knowledge about the lead poisoning issue. Similarly, positive self-conscious emotions included positive emotions with explanations that hinted toward their self-awareness of knowledge about lead poisoning and how to deal with it. For example, a student expressed that they felt confident and wrote "I felt confident because I know how to identify what lead poisoning is, how to calculate how much is leaving the blood, and be able to express/inform one on what should be done and

what the risks are." In this response, the student demonstrates their knowledge about lead poisoning and how to deal with it. Table 11 shows the categorized emotions along with the frequency for each category.

Table 11

Categorized Students' Expressed Emotions with Frequency

	Negative Emotions		Positive Emotions	
	Unpleasant Emotions	Self-conscious Emotions	Pleasant Emotions	Self-conscious Emotions
Total Frequency (as percentage of expressed emotions)	72 (37.7%)	28 (14.7%)	52 (27.2%)	39 (20.4%)
Emotions	Anger (10)	Anxiety (2)	Calm (1)	Accomplished (2)
	Annoyance (1)	Confused (3)	Comfortable (2)	Compelling (1)
	Despair (1)	Critical (1)	Compassion (1)	Concern (7)
	Devastated (1)	Disturbed (1)	Content (1)	Confident (6)
	Disappointed (3)	Guilt (2)	Empathy (2)	Curiosity (4)
	Disbelief (3)	Helplessness (2)	Excited (1)	Educated (2)
	Disgust (1)	Nervousness (3)	Feel good (10)	Empowering (3)
	Fear (2)	Shock (6)	Grateful (5)	Enlightened (2)
	Frightened (1)	Surprised (5)	Happy (3)	Informed (2)
	Frustration (6)	Unsettled (1)	Hopeful (7)	Interested (1)
	Heartbroken (1)	Worrisome (5)	Motivated (4)	Intrigued (1)

	Horrible (1)	Indifferent (1)	Optimistic (2)	Knowledgeable (4)
	Pity (1)		Peaceful (1)	Sympathy (4)
	Sadness (25)		Positivity (2)	
	Scared (3)		Relief (6)	
	Uncomfortable (1)		Safe (1)	
	Unpleasant (1)		Satisfied (3)	
	Upset (10)			

Note. The table shows my classification of students' expressed emotions into negative and positive emotions using Gu et al.'s (2019) theory. The further classification into unpleasant, pleasant, and self-conscious emotions is my addition after reading through students' explanations of their expressed emotions.

Table 11 shows that 37.7% of the total expressed emotions were unpleasant emotions, 14.7% were negative self-conscious emotions, 27.2% were pleasant emotions, and 20.4% were positive self-conscious emotions. The emotions of sadness, anger, and upset dominated the category of unpleasant emotions. The emotions of shock, surprised, and worrisome were prominent in the category of negative self-conscious emotions. The category of pleasant emotions was led by emotions like feel good, hopeful, and relief while emotions of concern, confident, curiosity, knowledgeable, and sympathy were noteworthy in the category of positive self-conscious emotions.

Our qualitative analyses of students' explanations of their expressed emotions resulted in finding different reasons why students experienced and expressed certain emotions. I discuss six major themes from students' responses as their reasons for expressing emotions below.

Theme 1: Empathy for Tenants and Children

The first theme I identified captured students' responses where students expressed empathy for tenants, families, and children who have lead poisoning or have to live in houses with lead poisoning issues. Students also identified tenants' struggle to choose between having a home or staying safe from lead poisoning, which we identified as a subtheme "tenant's dilemma". Tenant's dilemma is the difficult choice that tenants have to make between having a roof over their heads and their families by living in lead-poisoned homes or keeping themselves and their families safe from lead poisoning by leaving the houses with lead-poisoning issues but then they wouldn't have a place to stay. Students expressed emotions of sadness, pity, guilt, anger, sympathy, empathy, and compassion in their responses when discussing their views on the situation that families have to face by living in lead-poisoned homes. Within the Empathy for Tenants and Children theme, I identified four clustered sets of emotions students expressed, which I discuss individually below.

Unpleasant Emotions. Students dominantly expressed sadness as an emotion while talking about the tenants. One student wrote, "I felt bad for the children and the family in the video, as well as the families and children that were not in the video. Knowing that this is an issue for many residents of Syracuse is sad to think about." The student referred to the family they learned about in the video (New York Civil Liberties Union, 2019) shown on slide 2 as well as other families that they did not know about. The student also expressed sadness over the fact that the issue of lead poisoning affects "many residents of Syracuse." Another student captured the dilemma that tenants face in their written response, "it's sad that people who have a roof over their heads that they have to battle with the possibilities of lead poisoning and having a place to call home." The student identified the tenant's struggle between living a healthy life and living

under a roof. Some students expressed concern about the health of children living in houses with lead poisoning. One student wrote, “I am sad that this effect so many families and children in Syracuse and this is the very first time I am hearing about it. I am sad that these families have to live in these conditions and it's their only option.” The student shows concern about the living conditions of children while expressing sadness. The student also acknowledges that they weren’t aware of the lead poisoning issue, which speaks to the level of awareness that needs to be created to inform people so that the issue can be addressed. We also see evidence of tenant’s dilemma in the response when the student states that “it’s their [tenant’s] only option” to live in such conditions.

Some students expressed emotions of pity, and anger as they learned about the tenants’ living conditions. One student wrote that they felt pity for the families “because I feel bad for families that have no choice but to live in a hazardous house/apartment.” The student also identified tenant’s dilemma by stating that the tenants had “no choice”. Students also expressed anger at the existence of the lead poisoning issue when it could be avoided easily. One student wrote, “I feel angry for the families that have to deal with such an easily preventable issue.” The keywords in this response are “easily preventable issue.”

Negative Self-conscious Emotions. Some students expressed that they felt guilty after learning about the tenants’ situation. One student wrote, “I also felt guilty because I don't understand what it is like to deal with something like this, and it's unfair that anyone has to at all.” In this response, the student acknowledges their privilege of not having to deal with lead poisoning. The student also pointed out the unfairness of the situation that some people have to go through.

Pleasant Emotions. Another set of student responses captured emotions of empathy, and compassion for people living in lead-poisoned houses. One student wrote, “I felt kinda empathetic because I know what it feels like to not feel safe in my home so I understand the concern these people felt.” The student made a connection with their personal life of how they have experienced feeling unsafe in their home and that helped them empathize with the people who have to live in hazardous conditions with lead paint. Some students expressed similar thoughts while expressing slightly different emotions. One student expressed compassion by writing, “I feel for those people who live in these environments who have to choose between lead poisoning and having a roof over their head.” The student expressed concern about the living conditions of people and the challenge of being homeless or being health conscious while the student felt compassionate about the situation.

Positive Self-conscious Emotions. Students also expressed the emotion of sympathy for the tenants. One student expressed their sympathy for the affected people by stating, “it is still heartbreaking to know that parents have to deal with suffering of their child's health, even the child itself. Someone that young should never have to feel like they're at risk.” The student identified the challenge that parents face by knowing about the dangerous living conditions and being helpless about it. The student also expressed empathy for children as they felt that young people should not have to go through such experiences of risking their health.

Students expressed different emotions and the reasons for experiencing these emotions clustered together in this theme. The students identified the poor living conditions of the people, shared concern about the effect on people’s health, especially children, and tenants’ struggle of choosing a house over their health. Table 12 gives an overview of the emotion categories of students’ expressed emotions and the frequency for each emotion category for this theme. Table

12 also shows examples of students' expressed emotions and reasoning captured under this theme.

Table 12

Students' Expressed Emotions Under Empathy for Tenants and Children

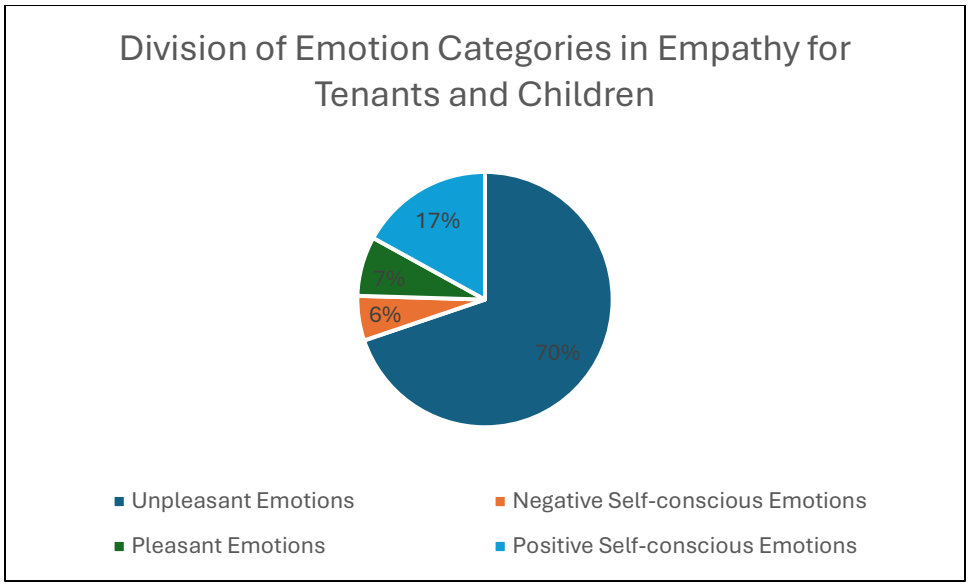
Emotions Category	Frequency (percentage)	Expressed Emotion	Reasoning
Unpleasant Emotions	37 (70%)	Sadness	"I felt bad for the children and the family in the video, as well as the families and children that were not in the video. Knowing that this is an issue for many residents of Syracuse, is sad to think about."
		Pity	"I felt these emotions because I feel bad for families that have no choice but to live in a hazardous house/apartment."
		Anger	"I feel angry for the families that have to deal with such an easily preventable issue."
Negative Self-conscious Emotions	3 (6%)	Guilt	"I also felt guilty because I don't understand what it is like to deal with something like this, and it's unfair that anyone has to at all."
Pleasant Emotions	4 (7%)	Empathy	"I felt kinda empathetic because I know what it feels like to not feel safe in my

			home so I understand the concern these people felt."
		Compassion	"I feel for those people who live in these environments who have to choose between lead poisoning and having a roof over their head."
Positive Self-conscious Emotions	9 (17%)	Sympathy	"It is still heartbreaking to know that parents have to deal with suffering of their child's health, even the child itself. Someone that young should never have to feel like they're at risk."

Figure 8 below shows the division of emotion categories in the Empathy for Tenants and Children theme.

Figure 8

Pie Chart of Emotion Categories in Empathy for Tenants and Children



Theme 2: Questioning Landlords/City Leaders

The second theme I identified captured students' responses where students asked direct or rhetorical questions about the intention and/or morality of people in power to eradicate lead poisoning. The people in power included landlords and city leaders. These students' responses were accompanied by expressed emotions of confusion, despair, anger, and curiosity. I found three sets of students' expressed emotions under the theme of Questioning Landlords/City Leaders.

Negative Self-conscious Emotions. Some students identified the role of landlords in maintaining the houses as per the housing code and were shocked and confused to learn about the housing situation in Syracuse. One student expressed their confusion by writing, "I understand it can be a hassle for landlords to fix the problem, but when it comes to human decency and public health, why not?" The student highlighted the value of human morals and people's health while being understanding of the hassle of maintenance work that a landlord has to do. However, the student compared the landlord's hassle with "human decency and public health" and asked why human decency and public health are not being prioritized here.

Positive Self-conscious Emotions. Another student expressed curiosity about the existence of lead paint in houses. The student wrote, "How do these things happen in the first place if they have been outlawed and deemed as harmful; wouldn't landlords and property managers see that as a loss in terms of money, not a profit?" The student is curious about how landlords can get away with doing something illegal and harmful to people. On the other hand, the student also questions the decision-making ability of landlords and their business sense by asking how landlords do not see a loss in renting out houses with lead poisoning issues. The student points out the fact that people will not rent out a house if they know it has lead paint and

that should result in losses for the landlord. However, the houses with lead-free paint are highly priced, as shown in the maps on Desmos slides 8 and 9 (see Figure 2), and affordability becomes a concern. This relationship between lower income or lower cost of living areas and lead poisoning is captured in detail in the next theme.

Unpleasant Emotions. In addition to questioning landlords, students also raised questions about the city leadership and their role in mitigating the lead poisoning issue. One student expressed anger and sadness at the situation by stating, “Although I'm sad, a sense of anger fuels me as I'm constantly reminded that [there] isn't anything being done to help the families. People of higher power have the ability and money to do so, which leaves me wondering why they won't do so.” The student questions why the people in authority are not playing an active role in solving the lead poisoning issue even though they have the power and funding to do so. Another student expressed despair by writing, “I felt despair because I genuinely would want to help these people but will the city [put] its first step forward in helping its people? This is a question we will never know, sadly.” The student expressed their desire to play a part in helping people while questioning the city leaders’ initiative to help the people they govern.

The second theme captured students’ emotions of confusion, curiosity, anger, and despair. The students elaborated on the reasons for feeling these emotions which revolved around the intentions of landlords and city leaders to help people with the available resources. The students also highlighted the value of human lives and morals above profits. Overall, the students point out the importance of the role of landlords and city leaders in resolving the lead poisoning issue. Table 13 gives an overview of the emotion categories of students’ expressed emotions and

the frequency for each emotion category for this theme. Table 13 also shows examples of students' expressed emotions and reasoning captured under this theme.

Table 13

Students' Expressed Emotions Under Questioning Landlords/City Leaders

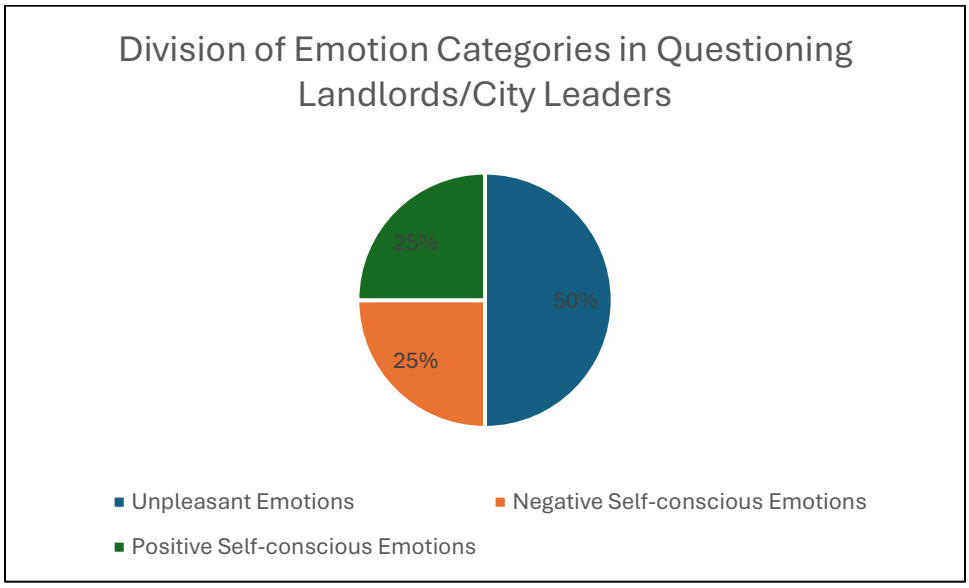
Emotions Category	Frequency (percentage)	Expressed Emotions	Reasoning
Unpleasant Emotions	2 (50%)	Despair	"I felt despair because I genuinely would want to help these people, but will the city [put] its first step forward in helping its people? This is a question we will never know sadly."
		Anger	"Although I'm sad, a sense of anger fuels me as I'm constantly reminded that [there] isn't anything being done to help the families. People of higher power have the ability and money to do so, which leaves me wondering why they won't do so."
Negative Self-conscious Emotions	1 (25%)	Confused	"I understand it can be a hassle for landlords to fix the problem, but when it comes to human decency and public health, why not."
Positive Self-	1 (25%)	Curiosity	"How do these things happen in the first place if they have been outlawed and deemed as harmful, wouldn't landlords and property

conscious Emotions	managers see that as a loss in terms of money not a profit?”

Figure 9 below shows the division of emotion categories in the Questioning Landlords/City Leaders theme.

Figure 9

Pie Chart of Emotion Categories in Questioning Landlords/City Leaders



Theme 3: Associating Lead Poisoning with Lower Income and Lower Cost of Living Areas

The third theme includes students’ responses that made a connection between lead poisoning and lower income or lower cost of living areas. In these responses, students shared their insights on areas that are heavily affected by lead poisoning. While working on the lead poisoning task, students viewed maps of Syracuse that helped them make a connection between lead poisoning and income levels. Students were shown two maps of Syracuse, one with lead poisoning levels in children, and the other with housing prices. Students concluded that areas with lower housing prices had high lead poisoning levels in children. Students expressed the

unpleasant emotion of sadness after finding this relationship between lead poisoning and the socioeconomic status of people.

Unpleasant Emotions. This theme was dominated by the emotion of sadness. Students felt sad to learn that people with lower income levels who live in areas with lower housing prices had higher lead levels among their children. One student expressed their sadness by stating, “While learning about how many families suffer from lead poisoning, I was sad to realize that primarily poor homes underwent this issue.” The same student expressed the extent of their sadness when they highlighted “harsh reality” of the living situation for people from lower income groups by saying, “As I saw the types of families that were forced to undergo this harsh reality with no assistance, it almost brought tears to my eyes.” The student pointed out that the families undergoing such hardships had no assistance in making their lives easier. Another student expressed their sadness as, “It is difficult to predict or have the knowledge of lead poisoning and if there is lead in the home and can lead to many health problems that might not be caught early especially in low-income households.” The student identifies the lack of awareness about lead poisoning and its existence in one’s home as a cause of major health problems. The student also highlighted the difficulty of detecting lead poisoning in low-income households.

The third theme captured students’ responses where they linked lead poisoning and the socioeconomic status of people affected by it. The responses showed how learning about lower-income households' challenge of tackling lead poisoning made the students experience and express sadness. Table 14 gives an overview of the emotion categories of students’ expressed emotions and the frequency for each emotion category for this theme. Table 14 also shows examples of students’ expressed emotions and reasoning captured under this theme.

Table 14

Students' Expressed Emotions Under Associating Lead Poisoning with Lower Income and Lower Cost of Living Areas

Emotions Category	Frequency (percentage)	Expressed Emotions	Reasoning
Unpleasant Emotions	3 (100%)	Sadness	"It is difficult to predict or have the knowledge of lead poisoning and if there is lead in the home and can lead to many health problems that might not be caught early especially in low-income households. While learning about how many families suffer from lead poisoning, I was sad to realize that primarily poor homes underwent this issue."

Theme 4: Need for More Proactive Action

The fourth theme includes students' responses that advocated for a need for more proactive action from the people and the city leaders to solve the issue of lead poisoning in Syracuse. Students expressed emotions of anxiety, upset, unsettled, feeling good, and worrisome with their responses that fall under this theme.

Negative Self-conscious Emotions. Some students felt that the current ongoing efforts were not enough to cater to the needs of people affected by lead poisoning. One student expressed their worry by stating, "I feel that there haven't been a lot of existing efforts to address the lead issue as people are uneducated about how long the lead blood levels take to reduce and

people are still getting intoxicated with lead due to lead paint in their houses, which should be gone as soon as possible." The student believed that the existing efforts were not enough and that there was a need to educate more people about the causes and long-lasting effects of lead poisoning. The response particularly mentions lead levels in the blood and continuous exposure to lead paint as the cause of it. The student argued that lead paint should be eliminated from houses. Students learned about the ban on lead paint during the lesson and this student was potentially using that ban as the base to support their argument of getting rid of lead paint "as soon as possible." Another student felt unsettled about the existing efforts. They said, "I feel this emotion because despite there being possible solutions to this problem, little if anything is being done to solve it." They believe that there are effective solutions, but the implementation of these solutions was not carried out as it should be, given the severity of the issue. This lack of implementation made the student feel unsettled. Another student expressed anxiety by stating, "I feel anxious because only those with the highest levels of poisoning are being helped; all those with traces of lead should be helped. As mentioned, there is no safe level of lead that can be in the blood." The student argued that all those affected by lead poisoning should be provided with assistance instead of focusing on the ones with the highest levels of lead poisoning. The student shared that there is no safe blood lead level, which makes it necessary to provide health care and financial support to all those affected.

Pleasant Emotions. Some students felt that the ongoing efforts to mitigate lead poisoning are good but there needs to be more efforts. One student wrote that they felt good knowing about the existing efforts, but the problem can be addressed in a better way. They wrote, "I feel like those efforts can be better addressed but those are definitely great starts towards progress." The student thinks that it is a good start but there is a need to do more.

Unpleasant Emotions. Some students argued for the need for a better policy to address the social justice issue. One student wrote, "This issue is systemic and could be addressed with well enforced policy. The fact that this problem exists at all upsets me." The student felt upset because of the lack of proper policy in place to support people affected by lead poisoning. The student believed that the issue is systemic and needs to be addressed at the policy-making level.

The fourth theme includes students' responses that discuss the need to spread awareness about lead poisoning among people, accelerate or add to existing efforts to mitigate lead poisoning, and a need for policy to eradicate the issue of lead poisoning. Students appreciated the knowledge of ongoing efforts by the city and community but feel that more needs to be done soon. Table 15 gives an overview of the emotion categories of students' expressed emotions and the frequency for each emotion category for this theme. Table 15 also shows examples of students' expressed emotions and reasoning captured under this theme.

Table 15

Students' Expressed Emotions Under Need for More Proactive Action

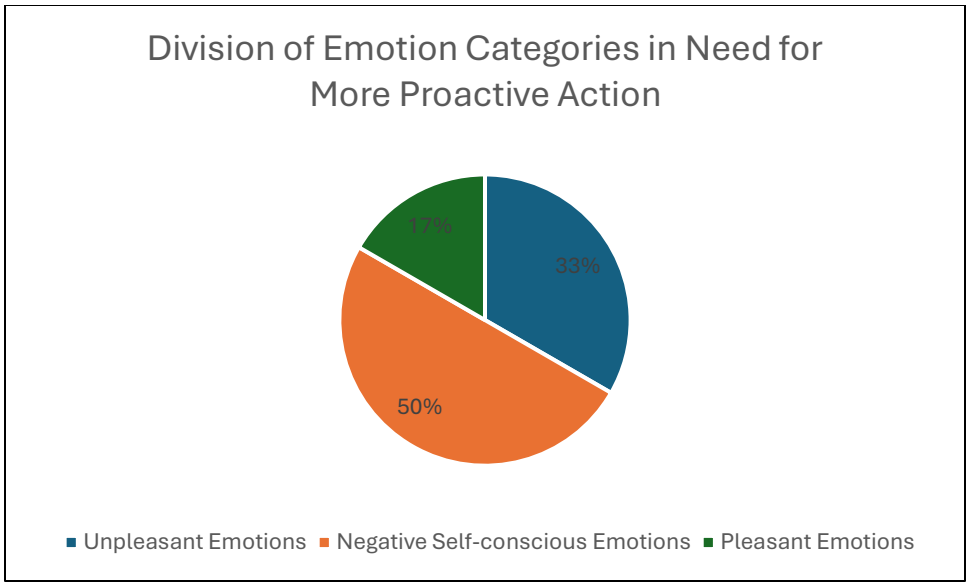
Emotions Category	Frequency (percentage)	Expressed Emotions	Reasoning
Unpleasant Emotions	2 (33%)	Upset	"This issue is systemic and could be addressed with well enforced policy. The fact that this problem exists at all upsets me."
Negative Self-	3 (50%)	Anxiety	"I feel anxious because only those with the highest levels of poisoning are being helped, all those with traces of lead should be helped.

conscious Emotions			As mentioned, there is no safe level of lead that can be in the blood."
		Unsettled	"I feel this emotion because despite there being possible solutions to this problem, little if anything is being done to solve it."
		Worrisome	"I feel that there haven't been a lot of existing efforts to address the lead issue as people are uneducated about how long the lead blood levels take to reduce and people are still getting intoxicated with lead due to lead paint in their houses, which should be gone as soon as possible."
Pleasant Emotions	1 (17%)	Feel good	"I feel like those efforts can be better addressed but those are definitely great starts towards progress."

Figure 10 below shows the division of emotion categories in the Need for More Proactive Action theme.

Figure 10

Pie Chart of Emotion Categories in Need for More Proactive Action



Theme 5: Usefulness of Course Content

The fifth theme includes student responses that expressed emotions about the usefulness of knowledge that they gained through the lead poisoning task. Students appreciated learning not only about lead poisoning, its effects, and methods of prevention but also about using mathematics to model and understand lead poisoning. Students expressed emotions such as being knowledgeable, safe, educated, empowered, confident, and happy. Within the Usefulness of Course Content theme, I identified two clustered sets of emotions students expressed.

Positive Self-conscious Emotions. In our analyses, we found that the students appreciated learning about the social justice issue of lead poisoning as well as using mathematics to understand the issue and model lead decay. One student expressed that they felt knowledgeable after the lesson by stating, “I feel like I am able to help make a change and be a part of something that is a major issue where I am living. I find it incredible that I am able to figure these mathematical equations out to help others.” The student felt knowledgeable after learning and using mathematical equations to model lead decay in blood so they could help others. The student also expressed a desire to play their part in bringing a change in society by

addressing the issue of lead poisoning now that they know of ways to prevent it. Another student stated that they felt empowered after the lesson because it supported their critical thinking. They wrote, “I was able to think critically and feel like I can have a voice.” The student also felt empowered and knowledgeable to have a say in raising awareness about lead poisoning and implementing solutions.

In addition to learning about the mathematical knowledge to understand lead poisoning, students felt educated, and confident after learning about the causes of lead poisoning and ways to prevent it. One student wrote that they felt educated because “I am now more educated on the [e]ffects of lead [poisoning] and the things I can do to prevent. Another student wrote that they felt knowledgeable by stating, “I feel knowledgeable and safer that I know how to prevent my home from having lead and how to help others.” The information about lead poisoning helped the student feel knowledgeable and safe now that they are equipped with information that could help them and their family stay safe. Some students felt confident and enlightened to learn about the effects of lead poisoning and ways to prevent it (see Table 16 for examples).

Pleasant Emotions. Students also expressed emotions of happiness, satisfied, and safe under this theme. One student felt happy after learning as they became knowledgeable about lead poisoning and learned usage of mathematics to model lead poisoning. They expressed their thoughts as “I felt happy because I am more knowledgeable about the lead issue and the calculations involved.” Another student expressed that they felt safe after learning about ways to prevent lead poisoning. They expressed this as, “I feel knowledgeable and safer that I know how to prevent my home from having lead and how to help others.” The student also mentioned that they felt knowledgeable after learning about lead prevention methods and how to help others as well.

The fifth theme captured students' responses that depicted students' appreciation for gaining knowledge on lead poisoning, its effects, and ways to stay safe. Students also felt educated after using mathematics to understand the lead poisoning problem and be able to perform calculations about lead decay in blood and bones through mathematical modeling with exponential equations. Table 16 gives an overview of the emotion categories of students' expressed emotions and the frequency for each emotion category for this theme. Table 16 also shows examples of students' expressed emotions and reasoning captured under this theme.

Table 16

Students' Expressed Emotions Under Usefulness of Course Content

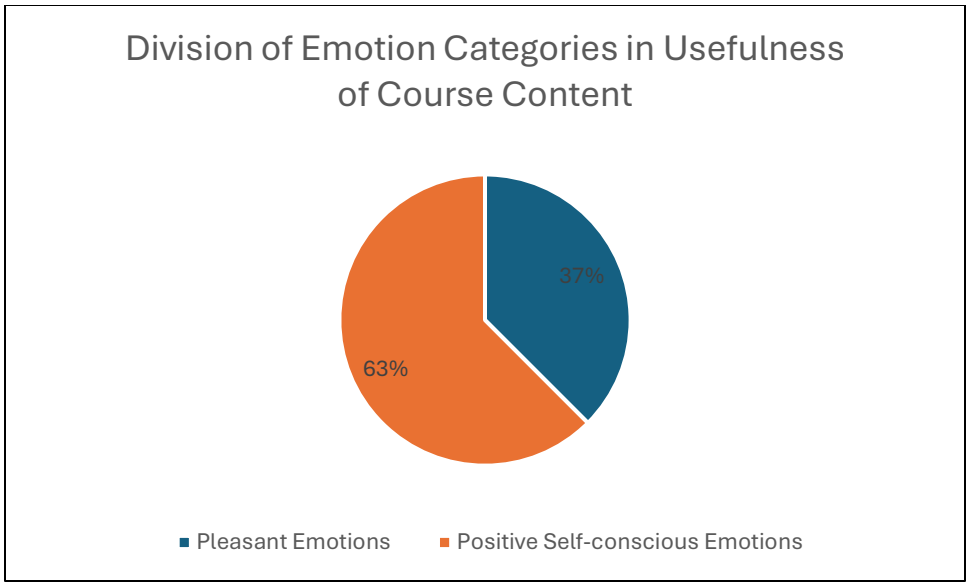
Emotions Category	Frequency (percentage)	Expressed Emotions	Reasoning
Pleasant Emotions	3 (37%)	Happy	"I felt happy because I am more knowledgeable about the lead issue and the calculations involved."
		Satisfied	"I completed this lab and learned about a social issue that affects the Syracuse community."
		Safe	"I feel knowledgeable and safer that I know how to prevent my home from having lead and how to help others."
Positive Self-	5 (63%)	Knowledgeable	"I feel like I am able to help make a change and be a part of something that is a major issue where I am living. I find it incredible

conscious Emotions		that I am able to figure these mathematical equations out to help others."
	Educated	"I am now more educated on the [e]ffects of lead [poisoning] and the things I can do to prevent."
	Empowering	"I was able to think critically and feel like I can have a voice."
	Confident	"I felt confident because I know how to identify what lead poisoning is, how to calculate how much is leaving the blood, and be able to express/inform one on what should be done and what the risks are."

Figure 11 below shows the division of emotion categories in the Usefulness of Course Content theme.

Figure 11

Pie Chart of Emotion Categories in Usefulness of Course Content



Theme 6: Views on Existing Solutions

The sixth theme I identified captured responses where students expressed emotions about the ongoing efforts to resolve the lead poisoning problem in Syracuse. Students expressed these emotions on slide 20, after they learned about the current efforts to address lead poisoning in the lead poisoning task. Students expressed emotions like optimism, hopeful, confident, enlightenment, positivity, gratitude, relief, and motivated. Within the Views on Existing Solutions theme, I identified two clustered sets of emotions students expressed.

Pleasant Emotions. Students expressed a wide range of emotions after they learned about the existing efforts to mitigate lead poisoning. Students felt optimistic about the future of the city. One student expressed their optimism by writing, "I feel optimistic that this issue can be fixed, and these problems can be spread and shared to help people stay safe and to prevent high lead blood levels." The student felt optimistic about the solutions that they learned about and the safety of people after those solutions were implemented. Another student wrote, "I think by the steps that the city is taking for lead poisoning, people are going to be more educated and now what to look for or identify the causes of lead poisoning which will slowly decrease it throughout

time.” The student felt hopeful about the steps that the city is taking to solve the lead poisoning issue. The student is also hopeful that, with time, people will have more awareness about the issue, and they will be able to identify and resolve causes of lead poisoning to eradicate it. Another student was relieved to know about the efforts as it will now result in improved health of the people in the community, especially young children. The student expressed their relief as “I felt relieved that there are organizations out there trying to help and better communities so that people's health won't be harmed. I am also relieved that young children's learning and development won't be affected as much with a greater awareness around lead poisoning.” The student was also relieved after learning about the efforts of organizations and the reduction in children’s developmental problems caused by lead poisoning. Another student felt grateful for the resources that help them stay safe such as testing kits. They wrote, “I feel grateful because there are tests and people that come and test to the water around me to make sure it is safe for consumption and has no lead in it.” Some students expressed that they felt peaceful “knowing that people are helping those in need” and motivated that “action is being taken to help those in the community and that there were people who were motivated to find solutions.”

Positive Self-conscious Emotions. Students also expressed emotions of enlightened and confident under this theme. One student felt confident after learning about the strategies to prevent lead poisoning and the solutions. They wrote, “I felt confident after these slides because it gave a plan and strategies that I believe will work in a positive way.” Another student felt enlightened after writing the letter to the mayor. They expressed their emotion by writing, “After writing the letter to the mayor and expressing my emotions, I believe that solving this issue is closer than I originally perceived.” The student mentioned that they believe the solution to the lead poisoning issue in Syracuse seems to be closer than their initial perception of the issue.

The students expressed mostly positive emotions after learning about the ongoing efforts to resolve the lead poisoning issue. The student responses mainly discussed the knowledge to create awareness, the availability of resources for solutions, and the city and community coming together to people in need. Table 17 gives a summary of the emotion categories of students' expressed emotions and the frequency for each emotion category for this theme. Table 17 also shows examples of students' expressed emotions and reasoning captured under this theme.

Table 17

Students' Expressed Emotions Under Views on Existing Solutions

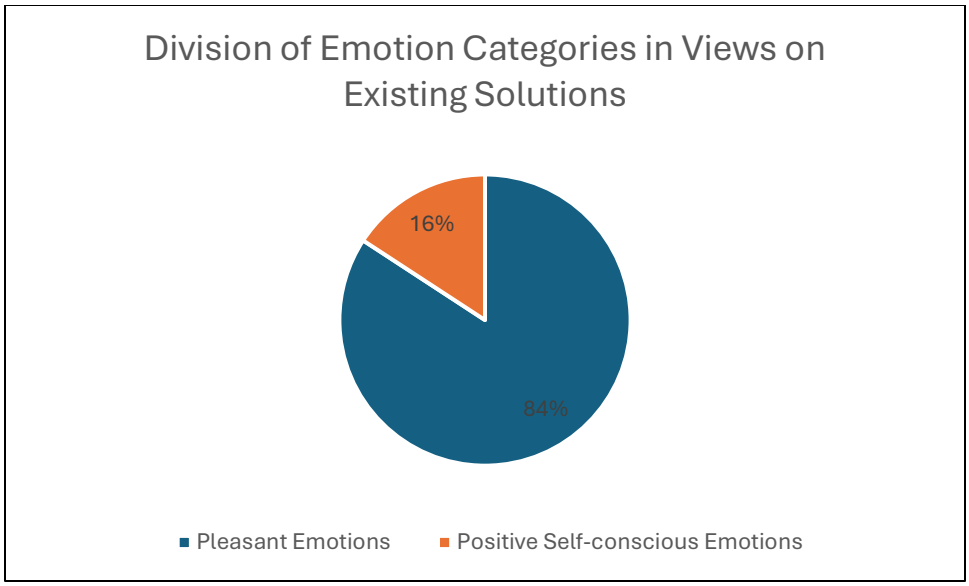
Emotions Category	Frequency (percentage)	Expressed Emotions	Reasoning
Pleasant Emotions	16 (84%)	Optimistic	"I feel optimistic that this issue can be fixed and these problems can be spread and shared to help people stay safe and to prevent high lead blood levels."
		Hopeful	"I think by the steps that the city is taking for lead poisoning, people are going to be more educated and now what to look for or identify the causes of lead poisoning which will slowly decrease it throughout time."
		Peaceful	"Knowing that people are helping those in need"
		Relieved	"I felt relieved that there are organizations out there trying to help and better communities so

			that people's health won't be harmed. I am also relieved that young children's learning and development won't be affected as much with a greater awareness around lead poisoning."
		Grateful	"I feel grateful because there are tests and people that come and test to the water around me to make sure it is safe for consumption and has no lead in it."
Positive Self-conscious Emotions	3 (16%)	Confident	"I felt confident after these slides [20-22] because it gave a plan and strategies that I believe will work in a positive way."
		Enlightened	"After writing the letter to the mayor and expressing my emotions, I believe that solving this issue is closer than I originally perceived."

Figure 12 below shows the division of emotion categories in the Views on Existing Solutions theme.

Figure 12

Pie Chart of Emotion Categories in Views on Existing Solutions



In my analysis of students' responses to slides 4, 22, and 23, I found that students expressed various emotions that I classified as pleasant, unpleasant, negative and positive self-conscious emotions. Students' written explanations informed me of the reasons for their expressed emotions. Overall, students dominantly expressed emotions like sadness and anger about the living situation of the tenants and expressed mostly positive emotions about the existing solutions to address lead poisoning in Syracuse.

RQ2: How does a lead poisoning mathematics task affect, if at all, college students' emotions as they work through the lead poisoning task in a precalculus class?

To answer the second research question, I divided students' expressed emotions (Table 10) into two parts: emotions after learning about the social justice issue, and emotions after learning about the ongoing efforts. In this section, I first discuss students' expressed emotions after learning about the lead poisoning issue. Then, I discuss students' expressed emotions after learning about the ongoing efforts to mitigate the lead poisoning issue. At the end, I discuss the emotions that students expressed at both points in the lead poisoning task (i.e., the emotions that

were common in students' responses after learning about the lead poisoning issue and the efforts to address it). In the findings for the first research question, I discuss themes as to why students expressed emotions throughout the lead poisoning task. In the findings for the second research question, I separately discuss students' emotions after learning about the lead poisoning issue and then learning about the ongoing efforts. Similarly, I discuss why students expressed emotions after learning about the lead poisoning issue and then after learning about the existing efforts to address lead poisoning. The focus of this section is on comparing the expressed emotions and the reasoning at two points in the lead poisoning task. It is important to note that the findings of the first research question informed the findings of the second research question.

There are two key findings: (1) students' emotions shifted, and (2) the reasons given for the same emotion shifted (e.g., anger). Students' expressed emotions shifted from mostly negative emotions after learning about the lead poisoning issue to mostly positive emotions after learning about the ongoing efforts. Some students expressed the same emotions at both points in the lead poisoning task but there was a shift in their reasoning for the same emotion. I discuss both findings below.

Students' Expressed Emotions After Learning About the Lead Poisoning Issue

Students expressed a total of 34 different emotions as they learned about the lead poisoning issue in Syracuse. These emotions are mostly negative emotions of sadness, fear, anxiety, disturbed, shock, upset, etc. with a few positive emotions of happy, motivated, grateful, empathy, and relief. Table 18 shows students' expressed emotions in categories with each category's frequency after learning about the social justice issue. The data in Table 11 is split into Table 18 (students' expressed emotions after learning about the lead poisoning issue) and Table

19 (students' expressed emotions after learning about the ongoing efforts). Table 19 is discussed later in the chapter.

Table 18

Categorized Students' Expressed Emotions After Learning About the Social Justice Issue with Frequency (slide 4)

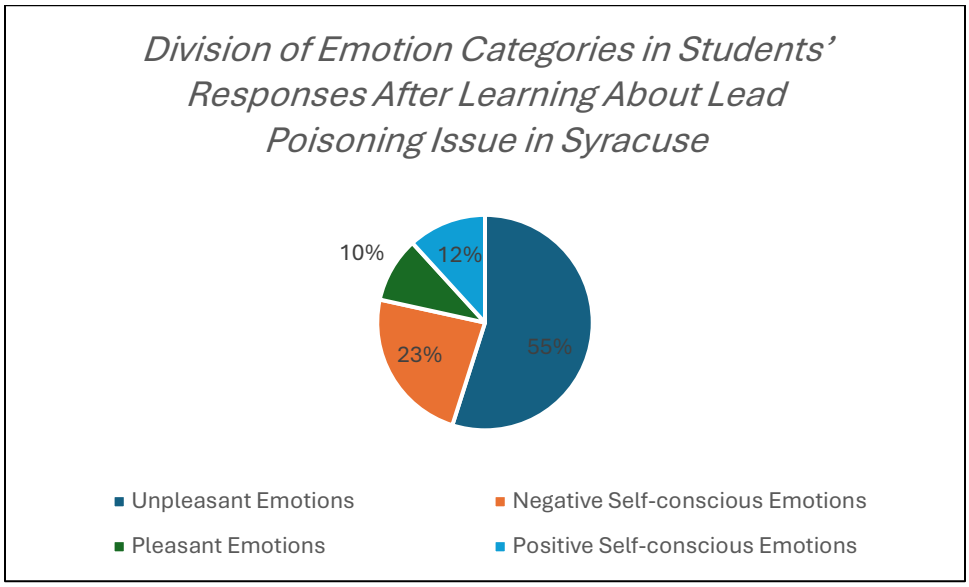
	Negative Emotions		Positive Emotions	
	Unpleasant Emotions	Self-conscious Emotions	Pleasant Emotions	Self-conscious Emotions
Frequency (percentage)	56 (54.9%)	24 (23.5%)	10 (9.8%)	12 (11.8%)
Emotions	Anger	Anxiety	Compassion	Concern
	Annoyance	Confused	Empathy	Curiosity
	Devastated	Disturbed	Grateful	Sympathy
	Disappointed	Guilt	Happy	
	Disbelief	Helplessness	Motivated	
	Disgust	Nervousness	Relief	
	Fear	Shock		
	Frightened	Surprised		
	Frustration	Worrisome		
	Heartbroken			
	Horrible			
	Pity			
	Sadness			

Scared
Unpleasant
Upset

Figure 13 shows a classification of emotion categories in students' responses after learning about the lead poisoning issue in Syracuse. We can see that 78% of students' expressed emotions were negative emotions and the remaining 22% were positive emotions. Students dominantly expressed unpleasant emotions of sadness, anger, upset, etc. after learning about the social justice issue making up 55% of the total expressed emotions on slide 4.

Figure 13

Pie Chart of Emotion Categories in Students' Responses After Learning About Lead Poisoning Issue in Syracuse



Unpleasant emotions was the dominant category for students' responses to the emotions question on slide 4 (see Figure 5 for slide 4). Students expressed emotions of sadness, anger, upset, frustration, etc. One student expressed their sadness by stating, "I am sad because the

children are getting lead poisoning that stays with them for life and the landlords don't care.” In this response, the student expressed their sadness particularly because of the long-term effects of lead poisoning on children and lack of care by the landlords regarding the health hazard. Another student expressed a similar feeling of sadness after learning about the magnitude of the lead poisoning issue and helplessness of the families suffering from it by writing, “I am sad that this effect so many families and children in Syracuse and this is the very first time I am hearing about it. I am sad that these families have to live in these conditions and it's their only option.” In this response, the student also highlights their lack of awareness about the lead poisoning issue in Syracuse. Some students expressed sadness after realizing the relationship between lead-poisoned homes and the socioeconomic status of residents residing in those homes. One student wrote, “While learning about how many families suffer from lead poisoning, I was sad to realize that primarily poor homes underwent this issue.” The student further elaborated on the depth of their emotion by stating, “As I saw the types of families that were forced to undergo this harsh reality with no assistance, it almost brought tears to my eyes.” Another student expressed sadness by pointing out the tenant’s dilemma. They wrote, “I feel sad for those families who are living in a home that has lead poisoning but cannot afford to move out a[nd] find a new place.” The student highlighted the affordability issue that Syracuse residents face that results in them residing in lead-poisoned homes.

In addition to sadness, students also expressed anger, upset, and frustration at the lead poisoning situation in Syracuse. One student expressed their anger by stating, “I feel angry because some people don't even know if they are surrounded by lead and that can negatively impact their health and if they do know some people don't have a choice to leave their homes to get away from it.” The student highlighted the lack of awareness among the people about lead

poisoning which results in them unknowingly becoming affected by lead. The student also highlighted the tenant's dilemma as they don't have a "choice" to leave their homes so even if they knew about the lead poisoning in their homes, they were helpless. Some students expressed anger and frustration on the lack of care by landlords and city leaders. One student wrote, "I'm angry because I don't understand how someone could own a house that knowingly puts people in danger." Another student wrote, "I feel angry and frustration that Syracuse's leaders will not take this issue more seriously." Both these students expressed their anger and frustration with the inactive stance of landlords and city officials to combat the issue of lead poisoning. The students questioned the morality of the landlords and city leaders because the landlords "knowingly put people in danger" and the city leaders wouldn't "take this issue more seriously." Another student highlighted the need for policy to address the lead poisoning issue while expressing their anger and upset. They wrote, "This issue is systemic and could be addressed with well enforced policy. The fact that this problem exists at all upsets me." A different student expressed frustration with the lack of care by people. The student said, "It is frustrating that people don't put in a[n] effort to help others and fix this issue. I am frustrated that people in power like the landlords don't help these families live a healthy life." The student mentioned "people" not putting in an effort to help each other in addition to the "people in power". The student felt that the Syracuse community was not actively helping each other stay safe from the lead poisoning and wants the community to come together as a single unit to eradicate lead poisoning from Syracuse. The unpleasant emotions expressed by students were mainly driven by empathy for families and children in case of sadness, and lack of care by landlords, people, and city officials for emotions like anger, frustration, and upset.

Some students expressed negative self-conscious emotions of shock, nervousness, and worrisome after learning about the lead poisoning issue. Some students expressed their shock at the existence of lead poisoning. One student wrote, “I was unaware that lead poisoning was still a thing and lead poisoning itself is a very dangerous thing to still have around.” Another student expressed their shock on landlords’ incapability to address lead poisoning issue in the houses and buildings that they own. The student wrote, “It’s shocking that a landlord, knowing the effects of lead poisoning, wouldn’t want to make the appropriate changes.” Another student expressed nervousness thinking of a time when they will have to move out of the newer University housing that is free from lead paint to a place that might have lead paint. The student stated, “I felt a bit nervous, knowing that once I am no longer living in the newer University housing, then I could be subjected to living in a place that also has high levels of lead.” A different student was worried about the health of children and wrote, “I feel worried for the children around the world that are getting bad health problems due to the issue of lead.”

Some students expressed positive emotions in their responses. These responses were mainly driven by the students’ lead-free childhood growing environment, availability of resources, desire to play their part in addressing the issue, and sympathy for children and parents facing the issue of lead poisoning. One student expressed their gratefulness by stating, “I'm grateful that I didn't have to grow up in an environment where I was worried that my younger siblings and cousins would develop lead poisoning in their system.” The student connected the lead poisoning issue with their identity by making connections between the lead-poisoned homes in Syracuse and their childhood home. Another student expressed gratefulness because of the availability of resources by writing, “I feel grateful because there are tests and people that come and test to the water around me to make sure it is safe for consumption and has no lead in it.”

The student is grateful that there are ways to test for lead poisoning in water and that their water source is checked to make sure there is no lead content in their drinking water. In this response, the student acknowledges the privilege of having safe drinking water. Another student expressed motivation to play their part in solving the lead poisoning issue in Syracuse. They wrote, “I feel motivated to learn more about the issue, and what I can do to help the issue in Syracuse.” Amidst these responses, a student expressed sympathy for the families and children who have to deal with lead poisoning. They stated, “I feel for the families that have to go through this, especially those with kids because sometimes the parents aren't the ones that can do something about it, it's normally the ones in a higher position that can. It's upsetting knowing that something can be done about it, and nothing is.” The student also highlighted that the people in “higher positions” are the ones who can do anything about the lead poisoning issue.

Students mostly expressed negative emotions after learning about the lead poisoning issue in Syracuse. Students were mostly sad, angry, and frustrated by the lack of care by landlords and city officials to support affected families. Students also expressed shock at knowing that lead poisoning still exists in Syracuse and worry for the health of families affected by it, especially children. However, there were some positive emotions as well. Some students expressed that they felt motivated to learn more about the lead poisoning issue and help resolve this issue. On the other hand, some students expressed positive emotions by acknowledging the privilege of not having to deal with the issue of lead poisoning while growing up and now as adults. These findings inform us about students’ expressions of mostly negative emotions as they learn about the lead poisoning issue. While designing the lead poisoning task, we anticipated that students would express all negative emotions after learning about the issue. However, in the findings I found that some students expressed positive emotions as well.

Students' Expressed Emotions After Learning About the Ongoing Efforts

In my analysis of students' expressed emotions and their explanations, I found that students expressed a total of 39 different emotions as they learned about the ongoing efforts to mitigate the lead poisoning issue in Syracuse. These emotions are dominantly positive emotions like accomplished, confident, empowering, hopeful, knowledgeable, optimistic, safe, etc. with a few negative emotions like anger, sadness, despair, frustration, etc. Table 19 shows students' expressed emotions in categories with each category's frequency after learning about the ongoing efforts.

Table 19

Categorized Students' Expressed Emotions After Learning About the Ongoing Efforts with Frequency (slides 22 & 23)

	Negative Emotions		Positive Emotions	
	Unpleasant Emotions	Negative Self-conscious Emotions	Pleasant Emotions	Positive Self-conscious Emotions
Frequency (percentage)	16 (18%)	4 (5%)	42 (47%)	27 (30%)
Emotions	Anger	Confused	Calm	Accomplished
	Despair	Critical	Comfortable	Compelling
	Disappointed	Indifferent	Content	Concern
	Frustration	Unsettled	Empathy	Confident
	Sadness		Excited	Educated
	Scared		Feel good	Empowering

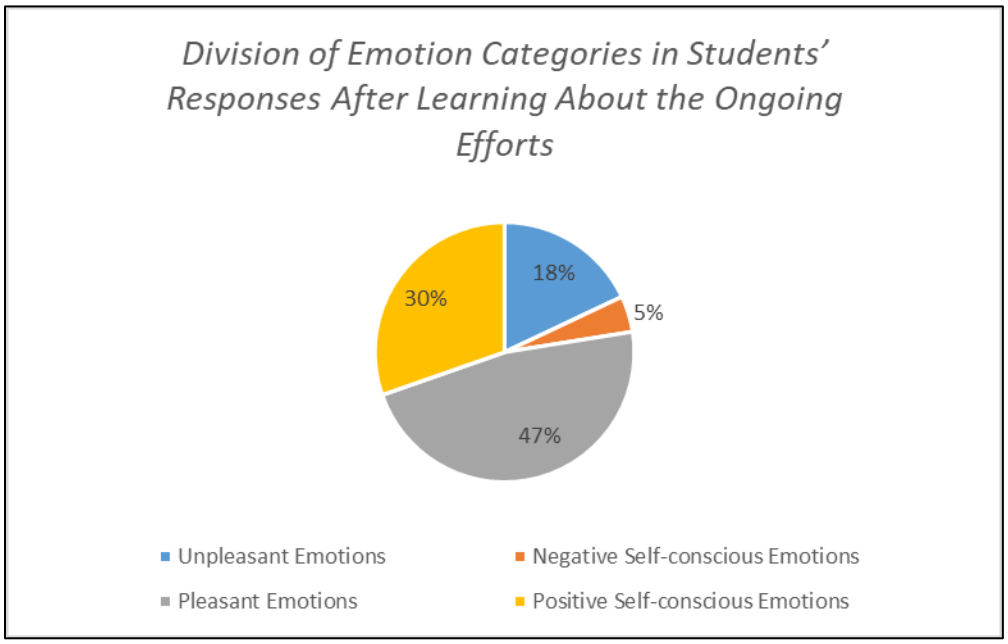
	Uncomfortable	Grateful	Enlightened
	Upset	Happy	Informed
		Hopeful	Interested
		Motivated	Intrigued
		Optimistic	Knowledgeable
		Peaceful	
		Positivity	
		Relief	
		Safe	
		Satisfied	

Figure 14 shows the division of emotion categories in students' responses after learning about the ongoing efforts. We can see that 77% of students' expressed emotions were positive emotions and the remaining 23% were negative emotions. This division between students' expressed negative and positive emotions is exactly the opposite of what we saw in the previous part (Figure 13) where negative emotions made a total of 78% of the students' expressed emotions while 22% were positive emotions. Students dominantly expressed pleasant emotions of hopeful, feeling good, relief, satisfied, etc. after learning about the ongoing efforts making up 47% of the total expressed emotions on slides 22 and 23. Positive self-consciousness emotions made up a total of 30% of the students' expressed emotions. These findings informed me that there was a shift in students' expressed emotions after learning about the ongoing efforts. Students' expressed mostly positive emotions after learning about the existing efforts to address

lead poisoning compared to mostly negative emotions after learning about the lead poisoning issue.

Figure 14

Pie Chart of Emotion Categories in Students' Responses After Learning About the Ongoing Efforts



Students' responses to emotion questions after learning about the ongoing efforts to mitigate the lead poisoning issue in Syracuse were dominated by positive emotions as shown by Table 19 and Figure 14. Students expressed pleasant emotions like feeling good, hopeful, and relieved as well as positive self-conscious emotions like feeling confident, empowered, and knowledgeable. One student stated that they felt good "to be knowledge[able] about lead and understand the major concerns that come with getting affected by lead poisoning and it also allows me to bring awareness about it to others around me and be able to voice my opinions on how to help." The student appreciated learning about the social justice issue and felt confident to "voice" their opinions to help others facing the lead poisoning issue. Another student appreciated learning about lead poisoning and ways to prevent it. The student wrote, "I feel better knowing

that I have learned more and have realized there are steps you can take to improve lead poisoning." Some students felt hopeful after learning about the ongoing efforts. One student highlighted one of the strategies to mitigate the lead poisoning issue led by an organization LeadSafeCNY. Students learned about different strategies on slide 20 of the Desmos lab. The student felt hopeful and wrote, "I think the efforts to address this [issue] are hopeful, especially the fourth strategy which moves to use the legal system to enforce change, I think its the most compelling because the law is enforced by the state, and so landlords don't want to be found doing illegal practices as it could be detrimental to their business." The student argued that the strategy focused on policy and legislation would be an effective way to keep the landlords in check. Another student wrote, "I think by the steps that the city is taking for lead poisoning, people are going to be more educated and [k]now what to look for or identify the causes of lead poisoning which will slowly decrease it throughout time." This student highlighted a different strategy of educating people and spreading awareness about lead poisoning. The student felt hopeful that the current ongoing efforts will help educate people so that they will be able to identify signs and causes of lead poisoning. Some students felt hopeful and relieved knowing that there are organizations working actively to address the lead poisoning issue. One student wrote, "I felt relieved that there are organizations out there trying to help and better communities so that people's health won't be harmed. I am also relieved that young children's learning and development won't be affected as much with a greater awareness around lead poisoning." The student also felt relieved knowing that increased awareness about lead poisoning would result in a decrease in learning and developmental issues in children. Another student expressed that they felt relieved knowing ways to identify and prevent lead poisoning. The student stated, "I feel

relieved that there are steps and solutions that I am now aware of that are attempting to solve this current problem."

Students also expressed positive self-conscious emotions like confident, empowering, and knowledgeable after learning about the ongoing efforts. One student wrote, "I feel more confident in my knowledge of the effects of lead levels in the blood, I feel much better now that I know this information. T[o] mitigate blood lead levels we can keep a clean a[nd] dust free home, use non lead paint and remove ourselves from lead concentrated areas." The student felt confident knowing the information about lead levels in blood and ways to avoid lead poisoning. Another student expressed a similar confidence in their learning of lead poisoning and its effects. The student stated, "I felt confident because I know how to identify what lead poisoning is, how to calculate how much is leaving the blood, and be able to express/inform one on what should be done and what the risks are." The student not only appreciated learning about lead poisoning but also the mathematics involved in calculating lead decay in blood. The student also felt confident in their ability to spread awareness about lead poisoning and the health hazards attached to it. Some students felt empowered after learning about ways to address lead poisoning. One student wrote, "It feels empowering knowing I can help." Another student highlighted that the lead-poisoning task helped them think critically and informed them enough to spread awareness about the issue. The student wrote, "I was able to think critically and feel like I can have a voice." Some students also felt knowledgeable and enlightened after learning about ways to identify and prevent lead poisoning. One student wrote, "I felt happy because I am more knowledgeable about the lead issue and the calculations involved." The student appreciated learning mathematics to understand the effects of lead poisoning. Another student felt enlightened after learning information about lead poisoning and stated, "I feel enlightened to be able to identify

the effects of lead levels in the blood because it means I know more about an issue that can cause such serious health issues in such a young population." Some students also made a connection with their identity and expressed that they felt knowledgeable and safe knowing that they can prevent their loved ones from lead poisoning. One student expressed these emotions as, "I feel knowledgeable and safer that I know how to prevent my home from having lead and how to help others."

On the other hand, some students expressed negative emotions after learning about the ongoing efforts. Students expressed negative emotions of sadness, disappointment, and upset. One student expressed that they felt sad because not a lot of people know about the lead poisoning issue and people are not actively addressing the issue. The student wrote, "I still feel sad that more people don't know about this and that people continue to not take the right steps to fix this issue." The student expressed their concern about the ongoing efforts and believed that more needs to be done to address the lead poisoning issue. Another student expressed sadness because they thought the city leaders are not doing a good job at addressing the lead poisoning issue. The student stated, "I felt sad because I feel the city of Syracuse isn't doing its best job in identifying and correcting the issue as lead can overall impact our future generation and it doesn't seem the care factor from the city is there." The student felt sad that the city leaders' lack of care was putting the future of Syracuse at stake. Another student expressed their disappointment in the efforts of city leaders by stating, "I felt disappointed as the city isn't doing its best to advocate for the people." Some students expressed negative emotions knowing he magnitude of the issue. One student expressed that they felt upset because "there [are] so many people going through this problem [lead poisoning] and it's affecting their lives in a major way."

Students' expressed emotions after learning about the ongoing efforts to address lead poisoning in Syracuse were dominated by positive emotions. Students felt good, hopeful, and relieved after learning about ways to identify and prevent lead poisoning. Students also expressed pleasant emotions knowing that now they have the knowledge to spread awareness about lead poisoning and help others facing this issue. Students were particularly relieved knowing that the prevention methods could help save children from lead poisoning. Students also expressed positive self-conscious emotions like confident, empowered, enlightened, and knowledgeable after gaining knowledge about preventing lead poisoning. There were a few expressions of negative emotions like sadness, disappointment, and upset, which were mainly driven by the lack of awareness among people, lack of care and initiative by city leaders, and the magnitude of the lead poisoning issue. These findings inform us about students' expressions of mostly positive emotions as they learn about the ongoing efforts. While designing the lead poisoning task, we anticipated that students would express all positive emotions after learning about existing efforts to address lead poisoning. However, in the findings I found that some students expressed negative emotions as well - 23% of the expressed emotions after learning about the ongoing efforts.

Emotions That Students Expressed at Both Points in the Lead Poisoning Task

Students expressed both positive and negative emotions at the two points in the lead poisoning task. Students expressed a total of thirteen emotions that were common at both points in the lead poisoning task. These emotions included anger, concern, confused, disappointed, empathy, frustration, grateful, happy, motivated, relief, sadness, scared, and upset. Even though students expressed the same emotions at both points in the lesson, their reasoning of why they felt those emotions gave me insights into how students felt the same emotions differently. Table

20 shows the list of emotions that students expressed at both points in the lead poisoning task. Table 20 also shows the respective categories of students' expressed emotions.

Table 20

Emotions That Students Expressed at Both Points in the Lead Poisoning Task

Negative Emotions		Positive Emotions	
Unpleasant Emotions	Negative Self-conscious Emotions	Pleasant Emotions	Positive Self-conscious Emotions
Anger	Confused	Empathy	Concern
Disappointed		Grateful	
Frustration		Happy	
Sadness		Motivated	
Upset		Relief	

Table 21 shows a comparison of students' reasoning for expressing the same negative emotions at both points in the lead poisoning task. Students' reasoning for expressing negative emotions at the beginning of the task was driven by empathy for families living in lead-poisoned houses and the lack of care by the landlords in maintaining safe housing for tenants. However, toward the end of the lesson, the reasoning for expressing the same negative emotions shifted to the large scale of the issue and the lack of care and initiative by the city leaders.

Table 21

Comparison of Students' Reasoning for Expressing Negative Emotions After learning About the Lead Poisoning Issue and After Learning About the Ongoing Efforts

	Reasoning

Expressed Emotion	After Learning About Lead Poisoning	After Learning About the Ongoing Efforts
Anger	"I'm angry because I don't understand how someone could own a house that knowingly puts people in danger."	"Although I'm sad, a sense of anger fuels me as I'm constantly reminded that their [there] isn't anything being done to help the families. People of higher power have the ability and money to do so, which leaves me wondering why they won't do so."
Disappointed	"There are small children living in dangerous environments and landlords do not do anything to help them."	"I felt disappointed as the city isn't doing its best to advocate for the people."
Frustration	"I felt this way because I am frustrated that this a common issue that can have a major impact on people."	"I am frustrated that this topic has not been resolved."
Sadness	"I feel sad for those families who are living in a home that has lead poisoning but cannot afford to move out a find a new place."	"I felt sad because I feel the city of Syracuse isn't doing its best job in identifying and correcting the issue as lead can overall impact our future generation and it doesn't seem the care factor from the city is there."

Upset	“I felt this emotion because it is something that I have never had to think about in my life before. Seeing that it can really harm someone's life without them even realizing it is really upsetting to me.”	“I still feel upset because there is so many people going through this problem and it's affecting their lives in a major way.”
Confused	“I understand it can be a hassle for landlords to fix the problem, but when it comes to human decency and public health, why not.”	“I have experienced concern while completing these slides. I am confused on why this issue hasn't be[e]n taken care of. It has been going on for a while now and people are vocalizing their suffering. I can't understand why there isn't a solution yet.”

Table 22 shows a comparison of students’ reasoning for expressing the same positive emotions at both points in the lead poisoning task. Students’ expressed positive emotions were mainly expressions of gratefulness and relief that they and their families didn’t have to deal with the issue of lead poisoning. Toward the end of the task, the expressions of gratefulness and relief were because of gaining knowledge about the lead poisoning issue and knowing about the current efforts to address the issue. At the beginning of the task, students shared concern and empathy for people affected by lead poisoning but toward the end of the task, these emotions were driven by a lack of proper action to address the issue. Students were motivated to learn

more about the lead poisoning issue at the beginning of the task and toward the end, this motivation shifted to creating awareness and helping the community.

Table 22

Comparison of Students' Reasoning for Expressing Positive Emotions After learning About the Lead Poisoning Issue and After Learning About the Ongoing Efforts

	Reasoning	
Expressed Emotion	After Learning About Lead Poisoning	After Learning About the Ongoing Efforts
Empathy	"I felt empathetic towards those who have to deal with this issue. Seeing children that are about the same age as my little sister made empathize better with them."	"I felt kinda empathetic because I know what it feels like to not feel safe in my home so I understand the concern these people felt."
Grateful	"I'm grateful that I didn't have to grow up in an environment where I was worried that my younger siblings and cousins would develop lead poisoning in their system."	"I'm grateful because I was able to gain more knowledge about this major concern in my school's area."
Happy	"The reason for that is because though the dorm hall had a lead problem but it was	"Knowing people are aware of the issue and are trying to help."

	fixed immediately before I moved in, so I should be safe."	"I felt happy because I am more knowledgeable about the lead issue and the calculations involved."
Motivated	"I feel motivated to learn more about the issue, and what I can do to help the issue in Syracuse."	"I am glad that action is being taken to help those in the community and that there were people who were motivated to find solutions. This made me feel motivated and inspired, myself to find solutions to problems that I, and friends around me, may face."
Relief	"I was relieved to realize that this issue is far from rampant where I am from, and that the risk of lead poisoning is far lower over there."	"I feel relieved that there are steps and solutions that I am now aware of that are attempting to solve this current problem."
Concern	"Hearing other peoples stories makes me worried to find a place that isn't dealing with lead poisoning."	"I am concerned due to the fact that no one has put a strategy into place in order to reduce lead poisoning. The

	"I feel concerned for the welfare of the children still subjected to live in those areas."	side effects are scary enough, and it should not come down to a death in order to make a change."

Overall, the findings presented in this section provide evidence that there was a shift in students' emotions after they learned about the ongoing efforts to resolve the lead poisoning issue in Syracuse. Students expressed more positive emotions after they learned about the ongoing efforts to address the issue of lead poisoning compared to after learning about the lead poisoning issue at the beginning of the lead poisoning task. Moreover, there was a shift in students' reasoning for expressing the same emotion after learning about the ongoing efforts compared to when they learned about the lead poisoning issue.

RQ3: How did college students self-report their mathematics learning experience after completing a lead poisoning mathematics task designed from a historically responsive literacy lens?

To answer the third research question, we analyzed students' responses to the lead poisoning lesson on Desmos (Figure 2) and the post-lab Qualtrics survey (Table 4). Our qualitative analysis informed us about students' development of historically responsive literacy's five learning pursuits: identity, criticality, skills, intellect, and emotion. On the other hand, students self-reported their development of the five learning pursuits on the post-lab survey, which informed our quantitative analysis. In this section, I discuss our findings for each learning pursuit by presenting the results of the quantitative analysis of the post-lab survey first and then sharing the qualitative analysis of students' responses to the lead poisoning task on Desmos. The

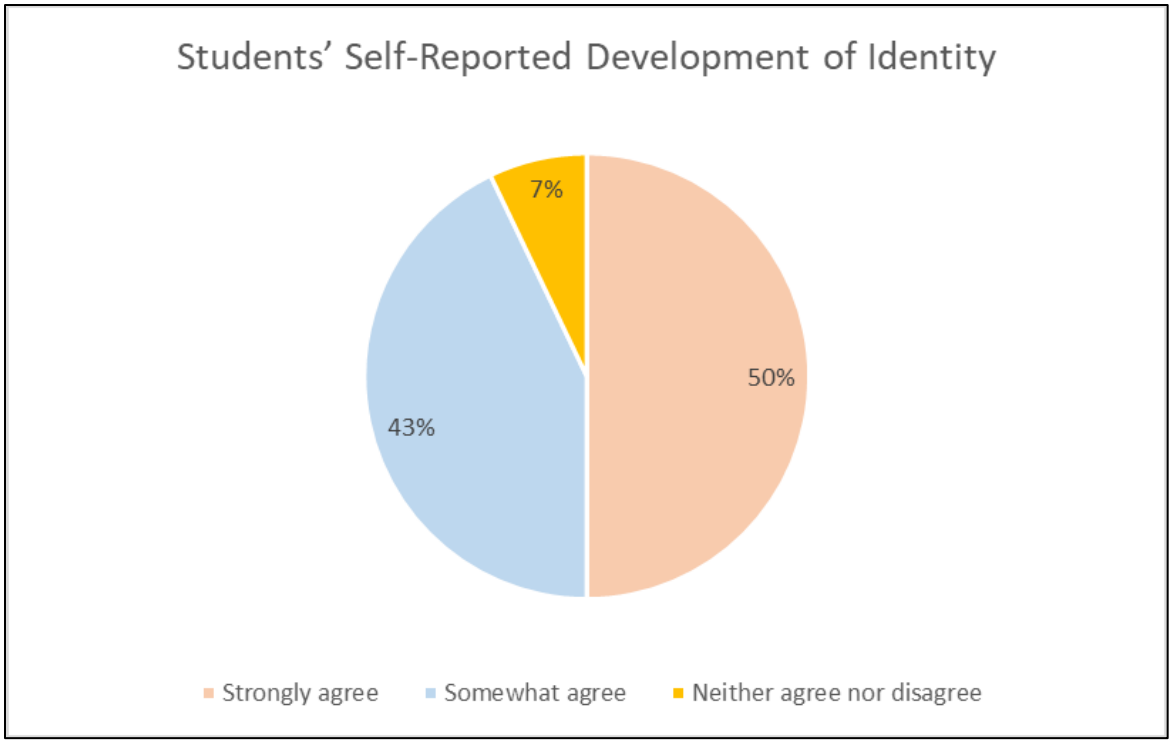
quantitative analysis provides insight into students' understanding of what they learned from the lesson and their understanding of whether the lesson helped them develop a certain learning pursuit. On the other hand, the qualitative analysis sheds light on the ways the students developed certain learning pursuits.

Identity

Students' Self-Reported Development of Identity. The students responded to five-point Likert scale questions on the post-lab survey. The question asked students to "rate how the lead-poisoning lesson helped students learn about themselves and others in their community." 50% of the students strongly agreed with the statement and another 43% of the students somewhat agreed with the statement. Only 7% of the students responded with neither agree nor disagree while no student responded with the somewhat disagree or strongly disagree options. Our findings show that the majority of students, 93% believed that they had learned about themselves and others in the community and hence developed identity. Figure 15 shows a pie chart of student responses to the identity question.

Figure 15

Students' Self-Reported Development of Identity



Different Ways Students Developed Identity. In our qualitative analyses of student responses to the lead-poisoning lesson on Desmos, we found that the students developed identity in three different aspects: (a) learning about themselves, (b) learning about/making a connection with their hometown, and (c) learning about the city they currently live in.

Learning About Themselves. Students expressed a sense of personal safety, and lack of awareness about lead poisoning and acknowledged their privilege of not dealing with lead poisoning as they developed their identity while learning about lead poisoning in Syracuse. A student stated that they felt happy because "though the dorm hall had a lead problem but it was fixed immediately before I moved in, so I should be safe." The key word here is the personal pronoun that the student used while expressing their happiness because now they should be safe from lead poisoning. Some students were concerned about their health now that they were aware of the lead poisoning issue. One student wrote, "The exposure to lead all around me leaves me

feeling anxious and scared especially the short and long term health issues as a result." The student shared a concern about their health because they learned that lead poisoning is a big issue in Syracuse. They were also concerned about the long-term effects it could have on their health.

Some students acknowledged their privilege and lack of information about lead poisoning because they never had to deal with lead poisoning in their lives or they had the financial resources to get rid of lead poisoning from their houses. One student stated, "I am privileged enough to have a roof over my head and financially stable. I know that if anything were to happen that would [affect] my living conditions, my parents would take care of it." The student acknowledges that their parents would step in and use their finances to keep them safe from lead poisoning. Another student wrote, "I am from a place that does not have to deal with a lot of safety issues and I feel guilty for having no health hazards when other places have so many." The student did not have to deal with the issue of lead poisoning while growing up, but they felt guilty after learning about the living conditions of people who have to deal with this issue. Some students learned about lead poisoning or its effect on health through the lesson. One student wrote, "I've never had to deal with the idea of lead poisoning so it's a new issue for me to think about." The student expressed their lack of knowledge about lead poisoning because they never had to deal with it. Another student stated, "I honestly have no clue, it is my first time hearing about this issue up here."

While working through the lead poisoning task, students learned about the health effects of lead poisoning and learned about and made connections to their personal safety. While some students expressed their lack of information about lead poisoning and realized their privilege of living in an environment free from the hazards of lead poisoning. We interpret these findings to

mean that the students learned about their privilege or lack of information about lead poisoning and developed identity.

Learning About/Making a Connection with Their Hometown. As students learned about the lead poisoning issue, they developed identity by making connections with their hometown. Students expressed concern for people living in their hometown or shared experiences of living in their hometown where they had (or did not have) to deal with lead poisoning. One student shared that they were not aware of lead poisoning in their hometown, but after learning about lead poisoning in Syracuse, they were concerned about their hometown because it is geographically close to Syracuse. They wrote, “I haven't heard of issues with lead poisoning in my area but I'm from Binghamton, NY so I wouldn't be surprised if we also have a problem because we aren't far from Syracuse and they are similar areas.” Another student shared that they do not have lead poisoning issue in their hometown but they have heard of lead poisoning issues elsewhere. They stated, “I have not heard of any widespread lead poisoning issues in my hometown, but I have heard of a few different water sources being contaminated in some more rural parts of Quebec.” Some students also shared their experiences of dealing with lead poisoning in their hometown. One student wrote, “There have been a few issues with it [lead poisoning] in old water fountains in the middle school I attended. However, it was taken care of right away so the issue never progressed.” The student shared that the lead poisoning issue was taken care of and it never grew into a large-scale problem. Another student shared that there might be a possibility of lead poisoning in their hometown but it is not that big of an issue to be talked about compared to Syracuse. They wrote, “As far as I know, there are no lead poisoning issues in my hometown, but it may be a smaller problem that is just not discussed as freely.”

Students developed their identity by making connections with their hometown and sharing experiences of dealing with lead poisoning in their hometown. Some students learned about the possibility of lead poisoning in their hometown because their hometown is similar to Syracuse and is geographically close by. We interpret these findings to mean that students learned about their hometown and made connections with the conditions in their hometown as they learned about the lead poisoning issue and developed identity.

Learning About the City They Currently Live in. Students also developed their identity by learning about Syracuse and expressing a sense of belonging (or not) to Syracuse. Students also learned about the lack of awareness about lead poisoning by the general population and expressed their concerns. Students expressed their sense of community in Syracuse in multiple ways. Some students shared their experiences of visiting Syracuse while growing up. One student wrote, "I grew up coming to Syracuse and going to the mall or other places here so I feel like I know the city pretty well just not the history as much." The student shared their experience of knowing the city but not being familiar with the history. Some students shared that they felt connected to Syracuse because of the diversity, friends, lifestyle, weather, school, or sports team. One student expressed that they felt a sense of community in Syracuse because "similarly to my hometown, there is a lot of diversity in people, community, and thought and I appreciate the difference in these things." Another student wrote, "I feel connected with Syracuse because it is a city and there are plenty of shops, restaurants, [and] activities to do. I feel connected with Syracuse because there is a reservation nearby and in different ways they honor Native Americans." The student expressed a sense of belonging to Syracuse because they liked the lifestyle. They also felt connected because there is a Native American reservation nearby and the people of Syracuse honor the Native Americans. Another student mentioned that they liked the

activities in Syracuse and felt connected because they go to school here and made friends here. They expressed this as “I feel more connected with Syracuse the longer I live here. I love the snow, I love to ski, and I love the people I've met at school here. I have made some of my best friends here.” A few students expressed their disconnect from the Syracuse community because they had different experiences growing up and were not fully aware of the history of Syracuse. One student wrote, “I feel welcomed within the University community with my friends, however, sometimes I feel disconnected from the culture of Syracuse itself. I did not grow up in an area that faced major economic disparities and socioeconomic barriers like they did, so I will never understand their struggle fully.” Even though the student felt welcomed at the university, they felt that they were not able to fully understand the history and lived experiences of people from Syracuse. The student felt disconnected because they weren’t able to understand the disparities.

Some students also developed identity by learning about the people around them. In this context, learning about the people around them translated to learning about the living conditions of the people and the lack of awareness about lead poisoning among the people. Students learned about the living conditions of the tenants and expressed empathy with the families dealing with lead poisoning. One student expressed their views on the living conditions of people by stating “I am sad that this [affects] so many families and children in Syracuse.” Some students acknowledged that the people had no other choice than to live in lead-poisoned houses. One student expressed it as “I feel for those people who live in these environments who have to choose between lead poisoning and having a roof over their head.” Students also learned about the lack of awareness and action by people. One student wrote, “Lead poisoning seems to just not be on people's radars when it's still a big deal.” Another student shared their view “It is

frustrating that people don't put in [an] effort to help others and fix this issue." Both these students highlight the lack of care by people when it comes to lead poisoning. This could be because of the lack of awareness about lead poisoning. One student wrote, "…it seems as though [lead poisoning] is being under-acknowledged as a widespread issue." Another student wrote, "I still feel sad that more people don't know about this and that people continue to not take the right steps to fix this issue." The students point out the lack of information among the people about lead poisoning and its scale. Another student shared that some people might not be aware if they are being lead-poisoned by their surroundings which can adversely impact their health. The student stated, "Some people don't even know if they are surrounded by lead and that can negatively impact their health."

Students learned about the community and expressed a sense of belonging to Syracuse. They also learned about the lack of care and lack of awareness by the community members and pointed out that there is a need to spread awareness about the issue. Overall, our qualitative findings align with the quantitative findings for students' development of identity. Students developed identity by learning about themselves, and the community around them, and making connections with their hometown.

Criticality

Students' Self-Reported Development of Criticality. The students responded to three five-point Likert scale questions on the post-lab survey focused on criticality. The questions asked students to rate how the lead-poisoning lesson helped students learn about real-world events and understand and develop righteous indignation toward lead-poisoning in Syracuse. 51% of the students strongly agreed with the statements and another 40% of the students somewhat agreed with the statements. 6% of the students responded with neither agree nor

disagree while 1% responded with the somewhat disagree and 2% with the strongly disagree options. Our findings show that the majority of students, 91% believed that they had developed a sense of righteous indignation toward the lead-poisoning issue in Syracuse and learned about real-world events, hence, developed criticality. Figure 16 shows a pie chart of student responses to the criticality questions.

Figure 16

Students' Self-Reported Development of Criticality

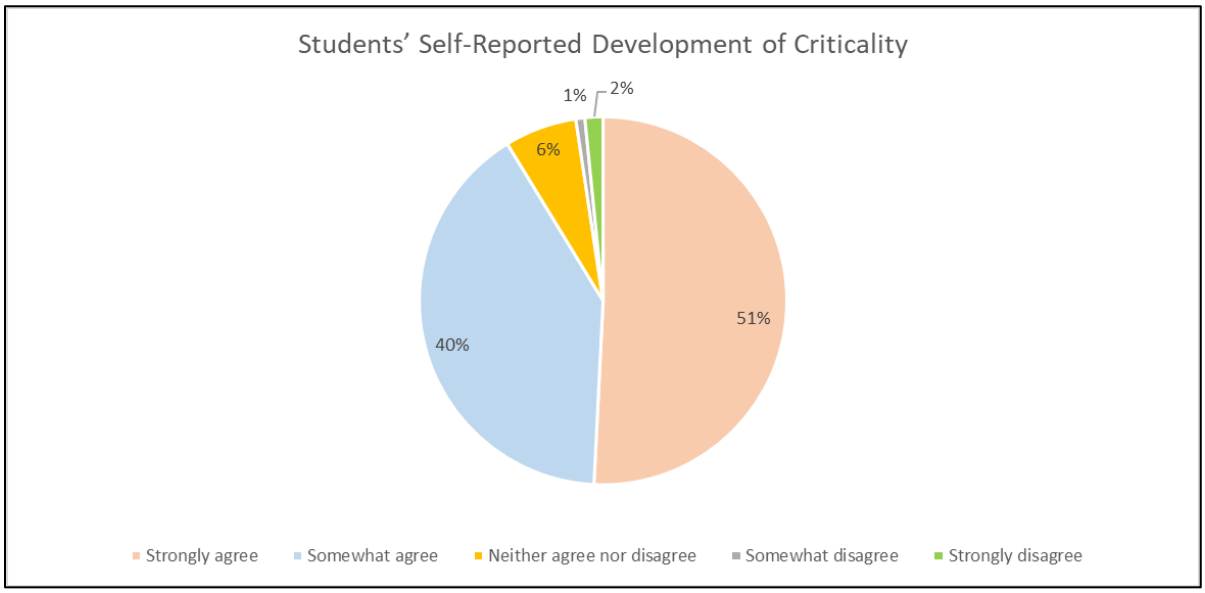
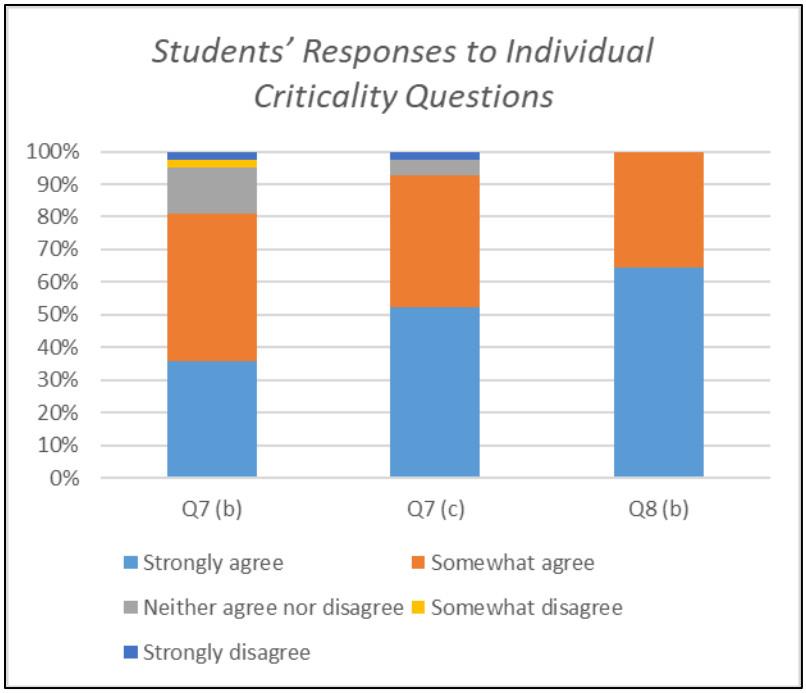


Figure 17 shows students' responses to each criticality question individually. We can see that in individual questions, most of the students chose strongly agree and somewhat agree options.

Figure 17

Students' Responses to Individual Criticality Questions



Different Ways Students Developed Criticality. In the context of the lead poisoning task, developing criticality refers to learning about the issue of lead poisoning, understanding the relationship between lead-poisoned houses and low-income areas, the living conditions of the tenants affected by lead poisoning, and the dangers of lead poisoning. Criticality also includes identifying the role of people in power to address the issue and raising voices to create awareness about the situation to help the affected tenants. Students developed criticality by (a) learning about the dangers of lead poisoning, (b) finding relationships between socioeconomic factors and blood lead levels, (c) learning about the living conditions of affected tenants, and (d) identifying and raising voices about the lack of care shown by people in power.

Learning About the Dangers of Lead Poisoning. Students developed criticality by learning about the short- and long-term effects of lead poisoning on people's health, especially children. In the letter to the Mayor, one student expressed the awareness of the dangers of lead poisoning by stating "It [lead poisoning] is very dangerous and can lead to many health care

problems, in relation to the blood, tissues and in the bones, these problems are irreversible." The student demonstrated their understanding of lead levels in blood, tissues, and bones and its irreversible harmful effects. Another student expressed concern about children's health and wrote "These health risks are of even greater concern among children who are more likely to obtain lead poisoning, usually through ingesting chipped paint." Another student was upset because of the long-term effect of lead poisoning on children. The student shared that children are not aware of the issue and it is hard for them to stay away from lead poisoning even when they are being "normal children". The student wrote, "The fact that the children are crawling and just being normal children and they still were exposed to lead poisoning, when they were not even trying to get into trouble which is really upsetting and now it can cause serious long-term effects." Another student shared their understanding of lead poisoning on health by sharing that exposure to lead can lead to "various health, cognitive, and social issues."

Finding Relationships Between Socioeconomic Factors and Blood Lead Levels.

Students learned about socioeconomic diversity in Syracuse and viewed maps with housing prices and lead levels in the city. Students were asked to predict relationships between socioeconomic factors and lead poisoning. Students made a connection between housing prices and blood lead levels from the maps. Students also watched the video and read articles about lead poisoning in Syracuse. These sources helped students to identify other factors like lower cost of living areas, population density, and older homes that were directly related to blood lead levels. One student predicted that highly populated areas will have higher blood lead levels. The student stated, "I think that the areas that will most likely be affected by lead poisoning are around the highways and the city area because it is more highly populated." The student provided reasoning for their prediction and stated, "This is because it [around the highway and

city areas] is more populated than other parts and cheaper homes." The student identified that the blood lead level would likely be higher in areas where the cost of houses is low. Another student pointed out that people with lower incomes likely do not have the resources to repair their homes that are poisoned with lead. The student wrote, "They are lower income homes which means they don't have money for repairs to old homes that contain these lead-contaminated walls." Students connected the low-cost houses with low-income individuals and deduced that low-income individuals or families will have limited resources to fix the older houses that contain lead paint which is why these houses are cheap and affordable.

Learning About the Living Conditions of Affected Tenants. Students developed criticality by learning about the living conditions of people affected by lead poisoning. This was an important step in helping the students understand the magnitude of the issue. Students expressed empathy with the tenants, especially children. One major part of developing criticality in this context was understanding the limited choices of the tenants and the difficult decision they had to make about choosing health or house. We referred to this challenge as the tenant's dilemma. One student identified the tenant's dilemma and wrote, "It's sad that people who have a roof over their heads that they have to battle with the possibilities of lead poisoning and having a place to call home." Another student expressed that they felt bad for families who had to deal with the issue of lead poisoning and were forced to live in dangerous conditions. They wrote, "I feel bad for families that have no choice but to live in a hazardous house/apartment." Students specifically shared their concerns about the health of children who have to live in such conditions. They also highlighted the struggle of parents who have to knowingly put their child's health in danger because of lack of housing options. One student wrote, "It is still heartbreaking to know that parents have to deal with suffering of their child's health, even the child itself.

Someone that young should never have to feel like they're at risk." Students also highlighted the role of landlords and city leaders in supporting tenants in staying safe. I will discuss that in the next theme of criticality. We interpret this set of student responses as evidence of students' criticality because students learned about the living conditions of people affected by lead poisoning, which helped them develop an understanding of the magnitude of the lead poisoning issue.

Identifying and Raising Voices About the Lack of Care Shown by People in Power.

Students developed criticality by understanding the role of people in power in addressing the lead poisoning issue. After students understood the lead poisoning issue and learned about the living conditions of the people, they were quick to identify the role of landlords and city leaders in addressing the issue. I define *the people in power* as the people who can modify the living conditions of the tenants and support people in getting rid of the lead poisoning issue. This primarily includes landlords who own the lead-poisoned houses and city leaders who control the resources and decision-making power. One student wrote, "I find it really grimy and low down that a problem that can [be] easily fixed [is not addressed] because of personal feelings of laziness or affordability." The student points out the "laziness" of people and "affordability" as the main reasons for not addressing the lead poisoning issue. Another student expressed that they felt sad because "the city is not doing anything to help families." Some students also highlighted the lack of care by people in general toward the issue. One student wrote, "I find it sad that this community hasn't done more for their people to address this issue. It took a college student 20 minutes to find a solution, meanwhile, the people running the city cannot put the time in to contribute?" The student pointed out that it was not difficult for them to understand the severity of the issue and a solution but the people in power have not given this issue proper consideration.

Students also highlighted the lack of care by landlords in making their houses safe for living. One student wrote, “This [lead poisoning] is still happening and landlords will not take the time to repaint or get rid of lead containing paint.” One student expressed that they were frustrated because “the landlords don't care about it [lead poisoning] or the children's health.”

Students also questioned the morality of the people in power concerning the efforts to address lead poisoning. One student expressed their surprise over the city officials' inability to find lead in a house when the owner of the house found it using a simple lead test kit. The student wrote, “I’m curious as to how the department that tested the paint missed the lead; despite the homeowner finding it with a simple at-home test kit.” Another student questioned the landlord by asking, “Why the landlord did not address the fact that there was lead paint in the apartments he was leasing. this will cause severe health issues if not taken care of.” The student points out that the landlord should have removed lead paint from the apartments before leasing to tenants. It seems like the landlord knowingly put the health of the tenants in danger. Another student stressed that “human decency” requires that we address this issue to safeguard people’s health. The student wrote, “I understand it can be a hassle for landlords to fix the problem, but when it comes to human decency and public health, why not.” One student questioned the Mayor in their letter and asked, “Do you not realize how the poorer families are forced to suffer from lead poisoning?” The student wanted to highlight that families with low income are primarily struggling with lead poisoning and are “forced” to live in hazardous conditions because of the lack of support from the city. Another student struggled to understand why there is still lead poisoning issue even after the use of lead paint was made illegal. They stated, “How do these things [lead poisoning] happen in the first place if they have been outlawed and deemed as harmful, wouldn't landlords and property managers see that as a loss in terms of money not a

profit?" The student makes a point that continuing to lease lead-painted houses will result in a loss for landlords because people will stop leasing their houses. Therefore, landlords should invest in making their houses lead-free to provide a safe environment for their tenants.

Some students appreciated the current ongoing efforts and applauded the role of city officials. However, they believed that there is a need to do more to fully address the lead poisoning issue. One student wrote, "I think it is nice that the government is supporting the funds in developing new houses, however, it will take a lot of time and money in order to fully rid the problem." The student mentioned that completely getting rid of lead poisoning will require more time and money, pointing toward the city funds. Another student expressed their thoughts on the existing efforts by stating, "It is a good start, but more needs to be done to ensure the safety of residents who live in homes with higher risks of lead poisoning." The student believed that there is a need to do more to ensure the safety of all. Another student highlighted the importance of investing in public policy by writing, "It is for these reasons that lead poisoning in Syracuse needs to be more heavily prioritized as a community wide health issue. I would recommend increasing budgeting towards public policy and legislation initiatives, to which only $50,000 has been invested into to date." The student pointed out that only $50,000 has been invested into public policy and legislation for addressing lead poisoning and recommends that this amount be increased and addressing lead poisoning be prioritized.

In summary, I found students developed criticality by understanding the lead poisoning issue, learning about the living conditions of people affected by it, identifying the relationship between socioeconomic factors and lead poisoning rates, and identifying the lack of care by landlords and city leaders in supporting the people affected by lead poisoning.

Skills

Students' Self-Reported Development of Skills. The students responded to two five-point Likert scale questions on the post-lab survey focused on skills. The questions asked students to rate how the lead-poisoning lesson helped them in learning exponential decay, modeling using exponential functions, and practicing mathematical skills. 54% of the students strongly agreed with the statements and another 38% of the students somewhat agreed with the statements. 8% of the students responded with neither agree nor disagree while no student responded with the somewhat disagree or the strongly disagree options. Our findings show that the majority of students, 92% believed that the lead-poisoning lesson helped them learn about exponential modeling and practice mathematical skills, hence, students developed the learning pursuit of mathematical skills. Figure 18 shows a pie chart of student responses to the skills questions.

Figure 18

Students' Self-Reported Development of Skills

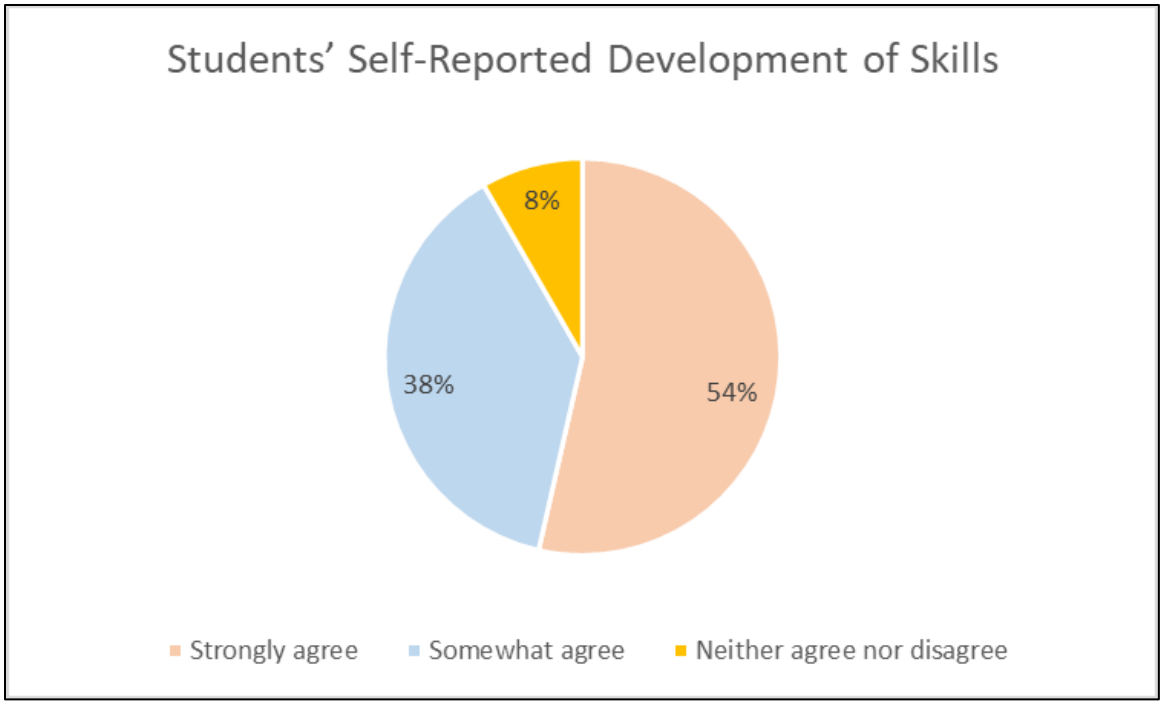
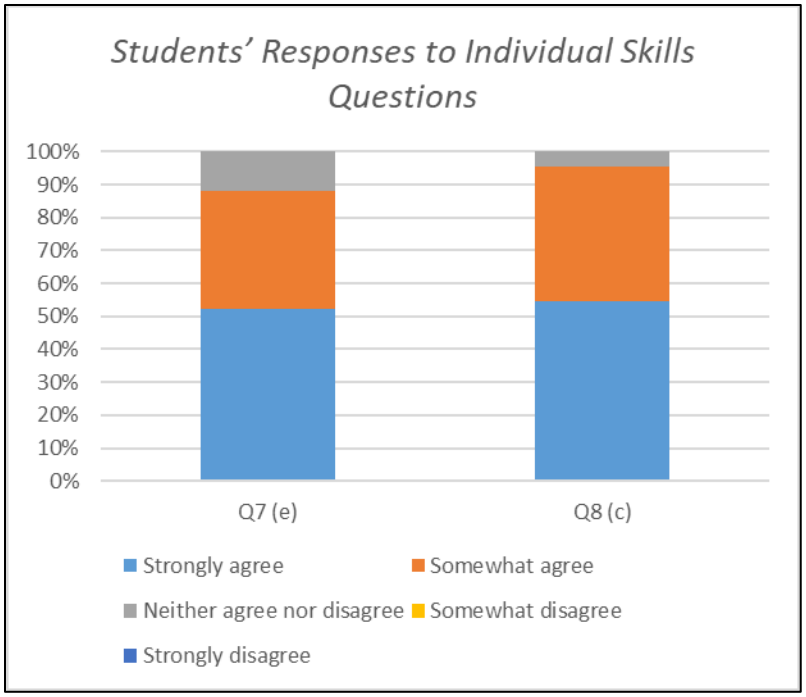


Figure 19 shows students' responses to each skills question individually. We can see that the majority of the students chose strongly agree and somewhat agree options in individual questions.

Figure 19

Students' Responses to Individual Skills Questions



Different Ways Students Developed Skills. Students developed mathematical skills as they worked on the lead poisoning task. I checked students' responses to the mathematical questions on the lead poisoning task for correctness. In the lead poisoning task, students correctly answered the mathematical questions (see Figure 2 for the questions), which tells us that they acquired the targeted mathematical skills. Students applied their knowledge of exponential functions to solve problems and reasoned with evidence for exponential functions. In addition, students understood and identified algebraic, graphical, and tabular representations of exponential functions. Students also demonstrated an ability to use maps and expressed a sense of geographical awareness. More importantly, students expressed their views on the usefulness of the course content in helping them apply mathematical knowledge to understand real-world problems.

In addition to the computational skills related to exponential functions, students also learned to analyze information shown in maps and make connections across maps. Students were

shown two maps of Syracuse: housing prices, and lead poisoning levels. Students were asked to analyze the maps and make a prediction about the lead-poisoned areas in Syracuse. Students were also asked to justify their predictions. Students made a connection between the low-priced housing areas and the areas with high lead poisoning levels. Students expressed the areas on the map using direction keywords like north, south, west, southwest, etc. Students were shown a set of values in a table and asked to plot the set of values on a graph and identify the relationship between the variables. Students successfully identified the exponential relationship between the values on the table and the graph. Students were given exponential functions word problems where they had to calculate blood lead levels. Students successfully calculated the blood lead level after the given intervals and provided reasoning for their solutions.

Some students shared their thoughts on the course content and its usefulness. One student wrote that they felt "[Encouraged] towards how my classes/degree is preparing me for my career." Another student expressed, "It makes me feel like I have the ability to think critically and problem solve." Both the students found the course content useful in preparing for career and thinking critically. Another student stated that they found the learning useful in helping others. They wrote, "I find it incredible that I am able to figure these mathematical equations out to help others." Another student expressed the same view of using the mathematical knowledge to help others by writing, "It feels good to be able to identify the effects of lead levels in blood. It feels good because if someone has it, I will be able to identify how much will be gone every 30 days and how long it will take for lead to leave the body." Some students appreciated learning about the causes and effects of lead poisoning and mentioned that they felt much more confident in being able to stay safe from lead poisoning. One student wrote, "I feel a lot better knowing that I

have become more aware on the risks and effects of lead poisoning. I also feel more comfortable knowing that there is something I can do to limit the risk of lead poisoning."

Students learned about different mathematical concepts related to exponential functions and found the learning useful and applicable in their lives. Students' responses to the mathematical questions on the lead poisoning task provided evidence of their learning of the mathematical content. Students acquired skills of identifying and modeling using exponential functions, using graphs, using multiple representations of exponential functions, and justifying claims with evidence. Overall, I interpret these findings as evidence of students' acquisition of mathematical skills because they responded to the mathematical questions correctly, followed the instructions to compute solutions to problems, and provided reasoning for their solutions.

Intellect

Students' Self-Reported Development of Intellect. The students responded to three five-point Likert scale questions on the post-lab survey focused on intellect. The questions asked students to rate how the lead-poisoning lesson helped them to apply and use mathematical knowledge to understand and address the lead-poisoning issue in Syracuse. 56% of the students strongly agreed with the statements and another 32% of the students somewhat agreed with the statements. 10% of the students responded with neither agree nor disagree and 2% responded with somewhat disagree while no student chose the strongly disagree option. Our findings show that the majority of students, 88% believed that the lead-poisoning lesson helped them connect mathematical knowledge to a real-world issue and apply mathematics to address the issue. Hence, students developed the learning pursuit of intellect through the lead-poisoning lesson. Figure 20 shows a pie chart of student responses to the intellect questions.

Figure 20

Students' Self-Reported Development of Intellect

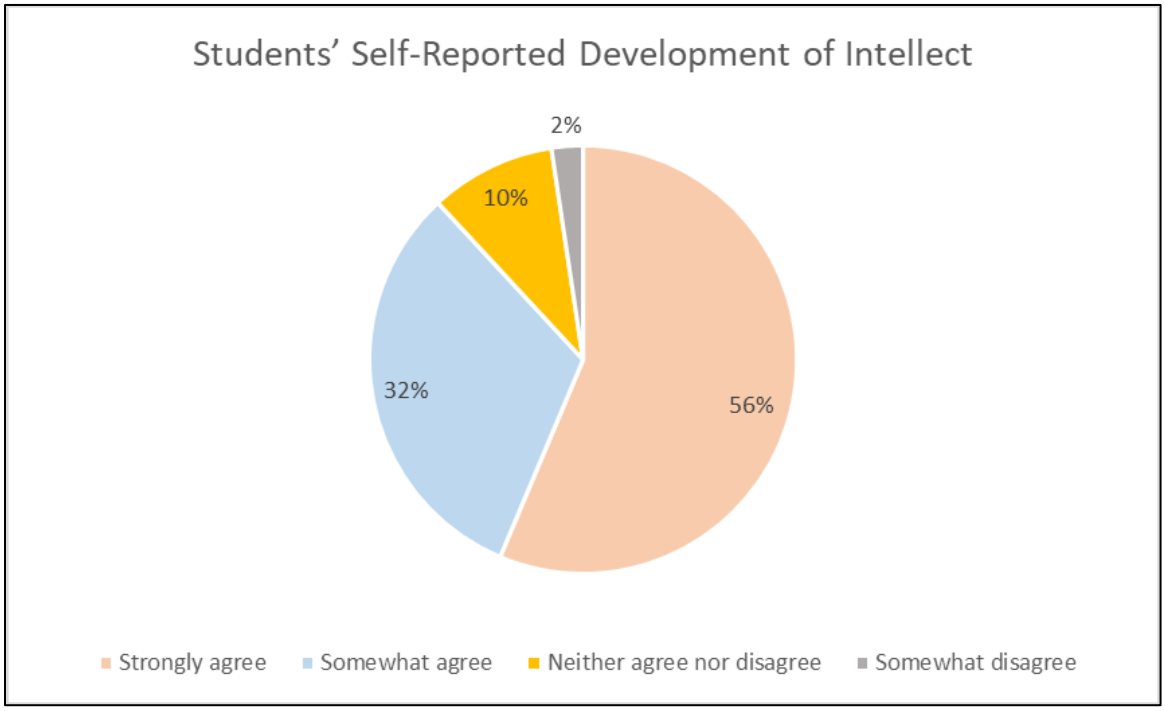
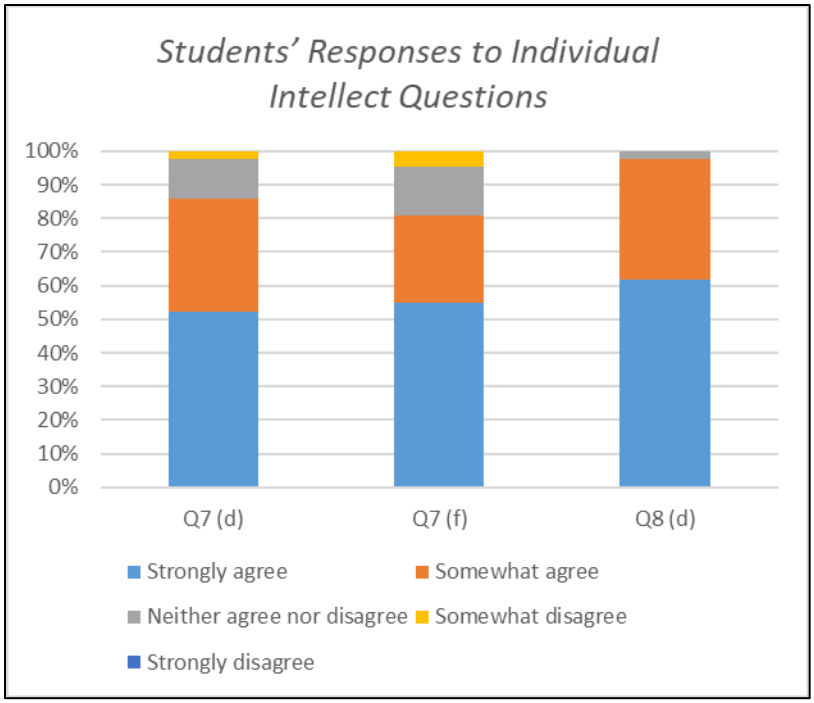


Figure 21 shows students' responses to each intellect question individually. We can see that at least 80% of the students chose strongly agree and somewhat agree options in individual questions.

Figure 21

Students' Responses to Individual Intellect Questions



Different Ways Students Developed Intellect. Students developed intellect during the lead poisoning lesson by applying mathematical knowledge to solve real-world problems, analyzing existing solutions to mitigate lead poisoning and their effectiveness, and brainstorming possible solutions. Students used their mathematical knowledge to interpret lead poisoning levels in different zip codes on the Syracuse map. Students also applied their skills in problems to find blood lead levels after a certain period. Students were informed about the ongoing efforts to address lead poisoning in Syracuse. Some students analyzed the existing efforts and shared their views on the efforts. One student wrote, "I feel like they [City leaders] have the right ideas when it comes to solving the issue but they have to continue their efforts and enhance the funding towards the problem." The student identified that the people in power are familiar with ways to mitigate lead poisoning and are on the right track to address this issue but need to allocate more resources to bring an effective change in the current situation. Another student expressed the same sentiments about the ongoing efforts by stating, "I think that the right actions are being

taken to address this issue but they need to continue and increase their efforts." The student highlighted the importance of continuing the efforts in addition to increasing the efforts. Another student expressed that they felt safe after learning about the plans to address lead poisoning. The student wrote, "The sources and strategized reduction plans made me feel safer." One student summarized the ongoing efforts as "To mitigate blood lead levels, education and awareness campaigns, better policy and renovating houses contaminated with lead paint are some solutions."

Some students also highlighted possible solutions to addressing lead poisoning. One student wrote a list of strategies that they believed could help reduce the lead poisoning situation. They wrote, "A few strategies I would like to suggest are: - Conducting lead testing in schools - Increasing awareness of lead exposure and prevention - Promoting other to clean dusty services - Keep housing areas well maintained -Run cold water over foods and beverages." The student listed some strategies different from the ones they learned about in the lesson. This tells us that the student was able to understand the causes of lead poisoning and brainstorm on different strategies that could help prevent lead poisoning.

Overall, I interpret these findings as evidence of students' development of intellect because students applied their mathematical skills to solve real-world problems involving blood lead level calculations, applied their knowledge of lead poisoning to analyze existing efforts to mitigate lead poisoning issue, and shared ideas about ways to prevent lead poisoning.

Emotion

Students' Self-Reported Development of Emotion. The students responded to two five-point Likert scale questions on the post-lab survey focused on the learning pursuit of emotion.

The questions asked students to rate how the lead-poisoning lesson helped them experience different emotions as they learned about the lead-poisoning issues and efforts to mitigate the issue. 32% of the students strongly agreed with the statements and another 39% of the students somewhat agreed with the statements. 20% of the students responded with neither agree nor disagree, 5% with the somewhat disagree and 4% with the strongly disagree options. Our findings show that the majority of students, 71% believed that the lead-poisoning lesson helped them experience different emotions and develop the learning pursuit of emotion. Figure 22 shows a pie chart of student responses to the emotion questions.

Figure 22

Students' Self-Reported Development of Emotion

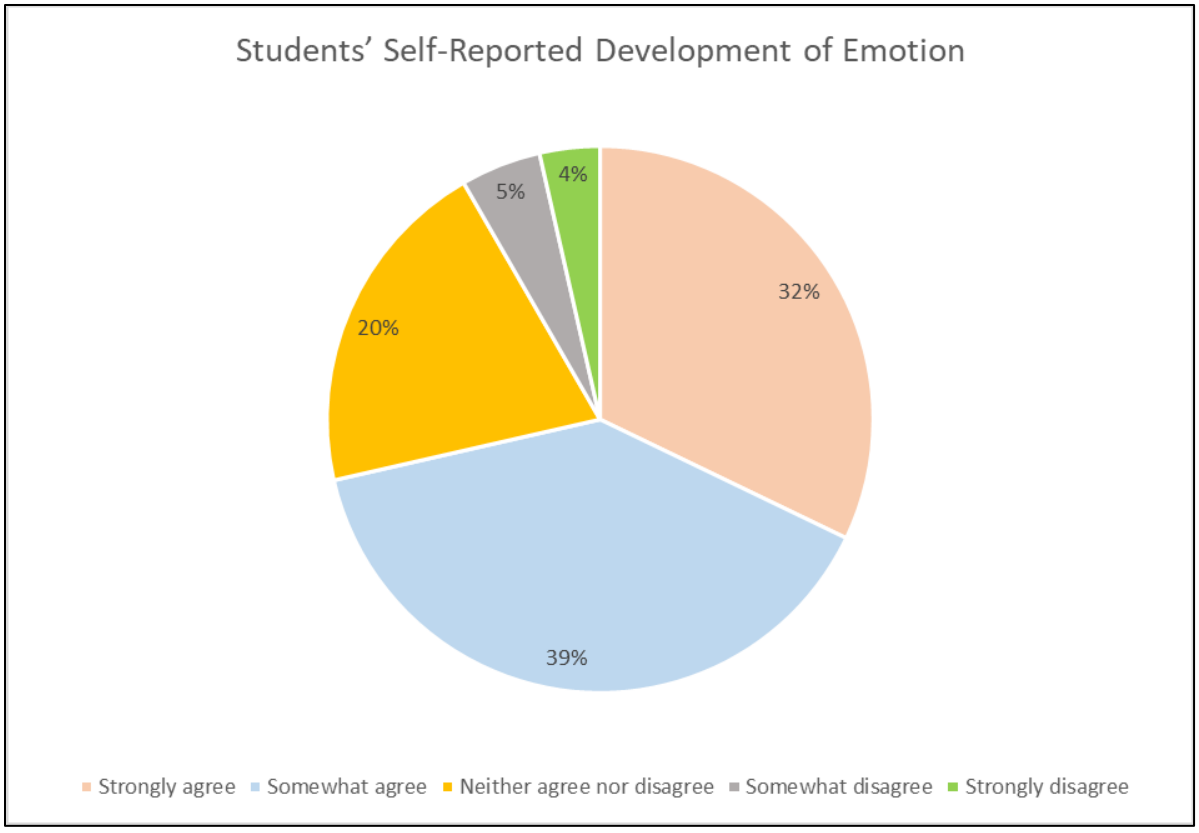
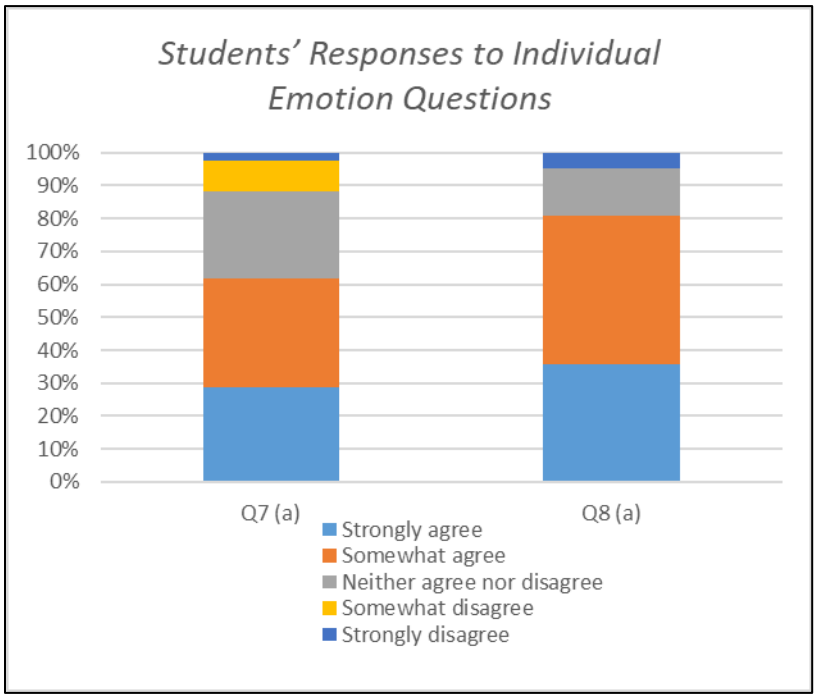


Figure 23 shows students' responses to each emotion question individually. We can see that at least 61% of the students chose strongly agree and somewhat agree options in individual emotions questions.

Figure 23

Students' Responses to Individual Emotion Questions



Different Ways Students Developed Emotion. Students developed the learning pursuit of emotions as they learned about lead poisoning and efforts to address lead poisoning while working on the lead poisoning lesson. I have shared a detailed overview of different emotions that students expressed earlier in the section (see Table 10 and Table 11 for lists of students' expressed emotions). The earlier section also sheds light on students' reasons for expressing emotions. We have also learned that students experienced a change in emotions during the lead poisoning lesson as they learned about the ongoing efforts compared to when they learned about

the lead poisoning issue (see Tables 18 and 19 for lists of students' expressed emotions at both points in the lesson).

Overall, our findings suggest that the lead poisoning lesson helped students in developing identity, criticality, skills, intellect, and emotion. Hence, mathematical learning took place since we defined mathematical learning as a combination of the five historically responsive literacy learning pursuits. The qualitative analysis of students' responses revealed that students articulated a total of 60 different emotions in their written responses to the lead poisoning task. Initially, after learning about the lead poisoning issue, students predominantly expressed negative emotions such as anger, sadness, and anxiety. However, after learning about the ongoing efforts to mitigate the lead poisoning issue, their emotional responses shifted towards more positive feelings, including hopefulness and relief. Overall, the findings indicated a significant emotional journey for students, moving from negative to positive emotions as they engaged with the content and learned about community efforts to combat lead poisoning. There was a notable transition from negative emotions after learning about the lead poisoning issue to positive emotions after learning about the community's efforts to address it. The qualitative analysis also identified reasons why students expressed emotions. I shared six major reasons in this research study: empathy for tenants and children, questioning landlords/city leaders, need for more proactive action, associating lead poisoning with lower income and lower cost of living areas, usefulness of course content, and views on existing solutions. Students self-reported their learning experiences, indicating development across five historically responsive literacy learning pursuits: identity, criticality, skills, intellect, and emotion. The qualitative and quantitative analyses revealed that students felt they gained a better understanding of the subject matter and their own identities in relation to social justice issues, highlighting the effectiveness of

integrating such themes into mathematics education. Overall, the findings emphasize the potential of using socially relevant topics in mathematics education to enhance emotional engagement, critical thinking, and a sense of agency among students, ultimately leading to a more meaningful learning experience.

Chapter 6: Discussion

This research study attends to the need to identify and address students' emotions in mathematics classrooms. Recent research in mathematics education highlights the importance of students' emotions in their mathematical learning (Kokka, 2019, 2022). This research study serves as a step to answer Kokka's (2022) call for further research on addressing students' emotions in mathematics classrooms. The findings highlight an array of emotions that students express in mathematics classrooms as they learn about a local injustice issue. Battey and colleagues (2022) argued that students find it challenging to engage with the mathematics lesson when their emotions are not addressed, and this research provides instructors with a list of emotions that they can anticipate in their classrooms when implementing social justice mathematics lessons. This research study also provides a different approach to assessing students' mathematical learning by incorporating learning pursuits of identity, criticality, intellect, and emotions in addition to mathematical skills (Fonger et al., in preparation).

This research study was guided by three research questions focused on: 1) students' expressed emotions and reasoning for expressing emotions, 2) change in emotions as they work through the mathematics task, and 3) students' self-report of their mathematical learning from a historically responsive literacy lens. The findings of this research shed light on different emotions that students express in a mathematics classroom as they learn about the lead poisoning issue and efforts to address it. The findings also highlighted students' reasoning for why they felt certain emotions. The findings also point out the change in students' expressed emotions as they learned about the ongoing efforts to mitigate the lead poisoning issue in Syracuse. I hypothesized that students would express negative emotions as they learned about the injustice issue and positive emotions as they learned about the ongoing efforts. However, some student responses

demonstrated students' expression of positive emotions as they learned about the injustice issue and negative emotions as they learned about the ongoing efforts. The reasoning for students' expressed emotions provided insight into their thinking to understand their expression of emotions better. The findings also suggest that students self-reported developing identity, criticality, skills, intellect, and emotions by engaging in the lead poisoning task.

Contribution to the Existing Literature

In Chapter 2, I discussed the importance of attending to students' emotions, curriculum that supports SJM, and support from the school as important factors in supporting students' mathematical learning in social justice mathematics classrooms. The findings of this research study contribute to the existing literature on all three factors that support students' mathematical learning.

Kokka (2022) presented a set of affective pedagogical goals to support students in identifying and resolving their emotions in a mathematics classroom. The findings of this research attend to one of the affective pedagogical goals of supporting students' identification of emotions. This research also analyzed changes in students' expressed emotions as they worked on the task. The findings about change in students' emotions could provide a starting point for further research on helping students resolve their emotions in a mathematics classroom.

Frankenstein (1990) and Gutstein (2003) argued in favor of a curriculum that supports critical mathematics or social justice mathematics goals of empowering students to use mathematics as a tool to understand the power structures in the society and develop critical consciousness. This research study provides an example of a lesson developed considering the social justice mathematics goals and its implementation in precalculus classroom. The study also

sheds light on students' mathematical learning as they completed the social justice mathematics task, the lead poisoning lab.

Kokka (2020) highlighted the role of support from the school in supporting students' mathematical learning. The lead poisoning lab was a part of precalculus students' regular instruction as a problem-solving lab. The inclusion of the problem-solving labs in the regular course instruction was a significant support from the school. Moreover, the course supervisor guided the precalculus instructors on the implementation of the lesson. The instructors were provided the lead poisoning lesson and did not have to spend time planning the lesson. The support from the school took some planning burden off the instructors' plates, which helped the instructors focus more on the implementation of the lesson to support students' mathematical learning.

In addition to the three factors discussed above, the instructors also used group work to teach the lead poisoning lab. Students were encouraged to work with partners to complete the problem-solving lab. However, this research study did not explicitly focus on the effectiveness of group work in supporting students learning. Future research could potentially explore the role of instructional methodologies in supporting students' mathematical learning.

Limitations

This research study was conducted with undergraduate students who attend college in Syracuse. Some students might not have strong feelings of attachment to Syracuse, the place in the context of the lesson. Their responses might be different if the context of their hometown was used. Similarly, the responses might be different if the students were local Syracuse high school students or had spent a considerably longer time residing in Syracuse. There was also tension in

using thematic analysis (Braun & Clarke, 2006) while knowing the historically responsive literacy theoretical framework (Muhammad, 2020, 2023). The knowledge of the framework might have influenced the coding process even though I did not map the framework onto the coding themes until the thematic analysis coding process was completed. One way to avoid this tension could be to analyze the data with a researcher unfamiliar with the HRL framework. A researcher unfamiliar with the HRL framework will likely analyze the data and identify patterns that are not influenced by HRL learning pursuits. Another way to approach this could be through deductive or a priori coding using the HRL learning pursuits as the initial codes to analyze data. In addition, we came across the issue of missing data. Two students from one of the precalculus sections did not complete the post-lab survey. The analysis of the Likert scale questions from the post-lab survey included responses from 41 students out of the 43 total students. This missing data problem affected the findings of the third research question. The missing data did not impact the findings of the first and second research questions because the post-lab survey responses were not used to answer the first two research questions. In this research study, we did not collect any data about the implementation of the problem-solving lab across the two precalculus sections. We did not have knowledge about the instructional practices used by the instructors to teach the lesson.

Implications

This research study contributes to the field in four different ways by providing insights into (1) engaging with students' emotions, (2) developing curriculum, (3) teaching mathematics by making it relevant to students, and (4) assessing students' learning.

The findings of this study provide instructors with a list of potential emotions that students may express in their classrooms during social justice mathematics lessons. This

knowledge about students' emotions can support instructors' lesson plans to address these anticipated emotions. Instructors can plan for the anticipated emotions and modify their lessons accordingly to help students resolve their emotions.

This study shared the results of implementing a social justice mathematics lesson. Although the study did not focus on examining the features of the lesson, teachers could use this lesson as an example of a lesson designed to incorporate the social justice mathematics goals (Figure 1). The findings of this research study showed how students' emotions changed during the lesson as students worked on the lead poisoning task. The lead poisoning task and the post-lab survey can be used as examples of careful wording of the tasks to elicit students' development of the five HRL learning pursuits. Teachers can use the lead poisoning lesson to guide the development of their own curriculum and tasks, contextualizing the local issues in the community.

The findings of this study shed light on the importance of contextualizing the local issues close to students' lived experiences. Students expressed their opinions about the usefulness of the course content, which was discussed in Chapter 5. Teachers can make mathematics relevant to students by inviting students to share contexts they would like to learn about and solve using mathematics. Gutstein (2003) referred to it as co-creating classrooms with the students. Co-creating classrooms is another factor that supports students' mathematical learning in social justice mathematics classrooms, as discussed in Chapter 2.

This research study presented a holistic view of understanding students' mathematical learning as they engaged with a social justice mathematics lesson. This research assessed students' mathematical learning by considering their learning about themselves and others as they engaged with the lead poisoning task, developed an understanding of the existing power

dynamics, acquired and applied mathematical knowledge to understand issues close to them, and expressed emotions as they do all of it using mathematics. Teachers may use this redefined mathematical learning to assess the learning of their students to include other elements in addition to the acquisition of mathematical skills.

Future Research

This research opens up new avenues for research exploring the role of task design in changing or resolving students' emotions. I found evidence that students found the course content useful for their learning. This was captured under the “Usefulness of Course Content” theme discussed in the previous chapter. This evidence encourages and motivates future research on the design of social justice mathematics tasks and its role in supporting students’ understanding of mathematical content. Further research can explore the role of task design in supporting students’ development of identity, criticality, skills, intellect, and emotions. Further research can also explore the other affective pedagogical goals of supporting students in resolving their emotions and developing social agency to take action for a positive change in their communities, challenging and disrupting oppressive systems. Mathematics education researchers can also explore the role of instructional practices in supporting and addressing students' emotions in mathematics classrooms. It would be interesting to see student responses when the same social justice lesson is taught to students who consider Syracuse their hometown.

Conclusion

In Chapter 1, I presented arguments for changing mathematics instruction to make the mathematical content relevant to students. Social justice mathematics provides a framework to achieve this goal by contextualizing students’ lived experiences. Social justice mathematics not only supports students in learning the mathematical content but also in learning about the issues

in their society and promotes the development of social agency in students so they can play their role in solving local problems. However, when students learn about issues in their society, they experience a wide range of emotions, which, if left unchecked, could result in students disengaging from the lesson. The importance of students' emotions in a mathematics classroom necessitated the need for this study.

The findings of this study provide insights into different emotions that students express in a social justice mathematics classroom. This study contributes new knowledge on how students' emotions changed as they learned about the existing efforts to address the local lead poisoning issue. Furthermore, the HRL learning pursuits offered the means to assess students' learning during the lesson. The findings suggested that students self-reported developing the five learning pursuits of identity, criticality, skills, intellect, and emotion as they completed the lead poisoning lab. This research study is not the end but rather a beginning of exploring the role of students' emotions in their mathematical learning and opens up multiple avenues for future research.

Appendix

Codebook from Qualitative Analysis

Code System	Memo	Frequency
Code System		1506
Connecting course content with hometown	Student makes a connection between their hometown and the course content.	1
Actions taken in hometown to prevent lead-poisoning	Student discusses different actions that were taken in their hometown to prevent lead-poisoning.	3
Lead-poisoning information from friends	Student mentions what they learned or heard about lead-poisoning from their friend.	1
Connecting lead-poisoning with hometown	Student makes a connection between lead-poisoning and their hometown.	40
Harming future opportunities for children	Student expresses a concern about children with lead poisoning and its impact on their future opportunities.	1
Leader's action	Student asks the city leaders to play their part in solving lead poisoning issue in Syracuse by using their voice and power.	1
Applying mathematics to understand/solve issue	Student uses mathematical knowledge/concepts to explain or understand lead poisoning issue or its effects or its solution.	125
Knowledge of exponential functions		0
Applying knowledge of exponential functions to solve problems	Student applies knowledge of exponential functions to solve problems	6
Reasoning with evidence for exponential functions	Student supports their claim with evidence to solve exponential function problems.	2
Understanding algebraic representation of exponential relations	Student demonstrates an understanding of algebraic expression of exponential functions.	2
Identifying exponential functions using table	Student identifies exponential relations by reading a table.	2

Identifying exponential function graphically	Student identifies exponential relations by looking at a graph.	2
Ability to use maps	Student showcases their ability to use maps	130
Sense of geographical awareness	Expresses a sense of geographical awarness. Key words are: right/ left (of the highway), outer/ inner (The city/ downtown), directions (north, south east, west) and words derieved from them, or usage of ZIP codes to identify locations.	100
Sense of community in Syracuse	Student expresses a sense of community with Syracuse.	31
Native Americans	Student expresses a sense of community with Syracuse because of Native American areas.	1
Diversity	Student expresses a sense of community with Syracuse becasue of its diversity.	3
Lifestyle	Student expresses a sense of community with Syracuse because of the lifestyle.	2
School/sports	Student expresses a sense of community with Syracuse because they go to school there or they support or are a member of the sports team.	17
Close to home	Student expresses a sense of community with Syracuse becasue it is geographically close to their hometown or areas that feel like home.	2
Siblings/Friends/Community members	Student expresses a sense of community with Syracuse because of the people they met here who made them feel welcomed.	12
Weather/environment as hometown	Student expresses a sense of community with Syracuse because the weather and/or the environment is similar to that of their hometown.	4
Disconnected with community	Student expresses a sense of disconnect from the community in Syracuse.	12
History of Syracuse	Student expresses a sense of disconnect with Syracuse because of its history of economic disparity and socioeconomic barriers.	1
Further questions/curiosity	What do students want to lewarn more about? What questions they have after watching the video?	30
Other sources of lead poisoning	Student wants to know about other sources of lead poisoning,	1

Health risk of lead poisoning	Student expresses curiosity to know more about health risks of lead poisoning.	1
Holding People Accountable	Student expresses a desire to know how people in authority could be held accountable/given responsibility.	7
Finding Solutions	Student expresses curiosity to know more about solutions to lead poisoning	10
Scope of the issue	Student expresses curiosity about knowing about how far spread is the lead poisoning issue.	6
Origin of the issue	Student expresses interest in knowing the origin of the lead-poisoning issue.	2
Surprised that lead poisoning is still a problem	Student expresses surprise that lead-poisoning is still an issue in today's world.	2
Reasons for emotions	According to students, why they expressed certain emotions	0
Sense of personal safety	Student expresses an aspect of their personal safety a a reason for feeling a certain emotion.	1
Change in Emotions	Students explicitly expresses that their emotions changed after completing the lab.	1
Views on existing solutions/efforts to mitigate lead poisoning	Student expresses their views on the current efforts/solutions to solve the problem of lead poisoning in Syracuse.	36
Need for more proactive actions	Student feels that the current efforts to mitigate lead poisoning are not enough and there is a need to do more.	28
Need to help all affected	Student expresses concern about helping everyone who has lead poisoning irrespective of their blood lead level.	1
Usefulness of course content	Student expresses their views on the usefulness of knowledge in the lab and skills they have gained through the lab.	21
Questioning landlords/city leaders/departments	Student asks direct or rhetorical question about the intention and/or morality of people in power to eradicate lead poisoning.	15
Acknowledging Personal Privilege	Student recognizes their social/economical/racial privilege. This includes privelege of not being from a place with lead poisoning.	5

Knowledge about lead poisoning and/or determination to help	Student shares their knowledge about lead poisoning and a desire to help the casue of solving lead poisoning issue.	101
Reasons behind lead poisoning		0
Associating lead poisoning with racial segregation/ redlining	Student associates lead-poisoning with racial segregation/redlining.	1
Associating lead poisoning with more populated areas	Student associates lead-poisoning with population density of areas.	2
Associating lead poisoning with older homes	Student associates lead-poisoning with older homes.	18
Associating lead poisoning with lower cost of living areas	Student associates lead-poisoning with areas that have a lower cost of living.	58
Associating lead poisoning with lower income areas	Students make a connection between lead poisoning and low-income neighborhoods.	42
Other sources of lead poisoning	Students identify what type of houses are likely affected by lead poisoning.	10
Easy to get lead poisoning	Student expresses concern about how easy it is to get high lead levels in the human body, especially children.	1
Awareness of lead poisoning	Student talks about level of awareness regarding lead poisoning (self or in more general sense), spreading awareness about lead poisoning or efforts to spread awareness about lead poisoning. This also includes instances where student expresses a need for increases in discussing lead poisoning and its dangers in the community. This could include instances wher students talk about solutions to lead poisoning.	36
Possible solutions	Student comments on the strategies discussed during the lesson and present their arguments for a certain strategy(ies).	2

	Worksite development	Student mentions development of safe worksites as a possible solution to address lead poisoning issue.	1
	Educate people	Student mentions educating people about lead-poisoning and creating awareness as a possible solution to address lead poisoning issue.	10
	Invest in lead testing	Student mentions investing in lead testing as a possible solution to address lead poisoning issue.	3
	Reducing lead-based materials	Student mentions reduction in using lead-based materials as a possible solution to address lead poisoning issue.	3
	Construction and renovation of homes	Student mentions construction of new homes and/or renovation of old homes as a possible solution to address lead poisoning issue.	24
	Use law/policy to solve social issues	Student mentions the use of law and/or policy to help solving the issue of lead poisoning.	15
	How to stay lead-free	Student expresses ways to stay safe from lead poisoning.	4
	Lack of experiecne in dealing with lead poisoning issues	Student expresses lack of personal experince dealing with lead poisoning.	7
	Introduction to lead-poisoning	Student expresses that they learned about the existence of lead-poisoning from this lesson.	2
Realization of dangers of lead poisoning		Stduent talks about lead poisoning being dangerous for people.	9
Aware of the health consequences of lead		Students express specific health risks caused by lead poisoning.	17
	Physical effects		3
	Behavioral issues		3
	Effect on child's development		6
	Learning issues		5
	Effect on blood, tissues, and/or bones		2
	Irreversible damage		5

long term effects		8
Effect on brain		13
Relating to family/friends/people in their hometown	Student makes a connection with family (including future family), friends, or people in their hometown while expressing their emotions discussing lead poisoning.	14
Relating to personal health/safety	Student express a certain emotion by making connection with their oersonal safety/health.	22
Empathy for tenants	Student expresses empathy for tenants/families who have to live in lead poisoned houses.	37
Tenant's dilemma		8
Empathy for children	Student expresses empathy for children who have lead poisoning or have to live in houses with lead poisoning issue.	44
Lack of awareness about lead poisoning	Student expresses a lack of awareness about lead poisoning issue by self or people in general.	0
By self	Student expresses a lack of awareness about lead poisoning issue by self	30
By people	Student perceives a general lack of care/awareness from people to solve lead poisoning problem.	14
Lack of funds or active action to fix lead poisoning	Student shares that lack of money and active action plan from the landlords and/or city leaders is the problem.	14
Lack of care by City leaders	Stduent perceives a lack of care from city leaders to solve lead poisoning problem.	11
Lack of care by landlords	Stduent perceives a lack of care from landlords to solve lead poisoning problem.	31
Expressed emotions	List of emotions that students expressed	0
Uncomfortable		1
Compelling		1
Indifferent		1
Positivity		2
Excited		1
Critical		1

Educated	2
comfortable	2
Anxiety	2
Horrible	1
Surprised	5
Safe	1
Enlightened	2
Despair	1
Accomplished	2
Unsettled	1
Interested	1
Peaceful	1
Happy	3
Intrigued	1
Satisfied	3
Optimistic	2
Empathy	2
Knowledgeable	4
Content	1
Calm	1
Informed	2
Helplessness	2
Empowering	3
Confident	6
Hopeful	7
Feel good	10
Scared	3
Disturbed	1
Worrisome	5

	Confused	3
	Disappointed	3
	Gratefulness	5
	Unpleasant	1
	Disgust	1
	Heartbroken	1
	Sympathy	4
	Devastated	1
	Feel bad	2
	Frightened	1
	Nervousness	3
	Annoyance	1
	Disbelief	3
	Motivated	4
	Concern	7
	Guilt	2
	Pity	1
	Curiosity	4
	Relief	6
	Compassion	1
	Fear	2
	Anger	10
	Upset	10
	Frustration	6
	Sadness	25
	Shock	6
No Emotion	Student explicitly mentions feeling no emotion.	3
Irrelevant information	Student expresses their views on the irrelevance of Syracuse lead poisoning information for them.	2

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Research Interest

- Students' mathematical learning of algebra and statistics
- Exploring students' emotions in social justice mathematics classrooms
- Examining task design principles that help address student emotions in social justice mathematics classroom
- Developing mathematics lessons incorporating students' social, cultural, and historical identities
- Mixed-methods research design and quantitative methods

Research Experience

2023-2023	Research Assistant working with Dr. Nicole Fonger
2022-present	Member of the Meaningful Math Research Group led by Dr. Nicole Fonger
2020-2021	Graduate Research Assistant: *Exploring the Nature of the Co-emergence of Students' Representational Fluency and Functional Thinking*, Syracuse University, Syracuse, NY

Research Projects

- Supporting Students' Mathematical Justification Through Instructor Endorsed Sociomathematical Norms in a Pre-Service Elementary Teachers Undergraduate Mathematics Class. (IRB# 22-095) [as PI]

Teaching Experiences

College

I have served as the Instructor of Record for various mathematics courses from Spring 2020 to Summer 2023. The courses include:

- Probability and Statistics for the Liberal Arts I (MAT 121)
- Precalculus (MAT 194)
- Foundational Mathematics via Problem Solving I (MAT 117)
- Foundational Mathematics via Problem Solving II (MAT 118)
- Elementary Probability and Statistics II (MAT 222)

Fall 2019 Teaching Assistant in Methods and Curriculum in Teaching Mathematics (SED 413/613)

K-12

2017-2019 High School Math Teacher – Lahore American School (Lahore, Pakistan)
Transition to College Mathematics and Statistics
Integrated Mathematics 2 and Integrated Mathematics 3
Geometry and Algebra 2
Member of the Staff Social Life Committee
Prepared students for the International Kangaroo Mathematics Contest
Middle School Soccer Coach

2016-2017 IGCSE Math Teacher – Roots IVY International (Lahore, Pakistan)
Teaching mathematics to grades 7-9

2014-2016 Primary & Middle Years Math Teacher–Beaconhouse TNS (Lahore, Pakistan)
Teaching mathematics to grades 5-6
Grade 4 homeroom teacher

Service

2023-present Co-President of School of Education Graduate Student Council

2020-present Mathematics Consultant

- Helped HEOP and SSS students at Syracuse University with various mathematics courses.

2012 Senior Volunteer

- Worked at The Citizen's Foundation to organize a summer camp for underprivileged students in the suburbs of Lahore, Pakistan.

Professional Organizations

2023-present AERA

Papers

Fonger, N. L., **Raja, W.**, Caviness, S., & Odiwuor, B. (Submitted Dec 2023). *Making undergraduate mathematics meaningful with historically responsive literacy and social justice mathematics*.

Caviness, S. L., Fonger, N. L., Voyias, K., Njue, E., Odiwuor, B., **Raja, W.** (October 2023). *"It was meaningful because [this] is now my home": Locality-identity and social justice mathematics.* Paper presented at the 45th Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education, Reno, NV.

Fonger, N. L., Caviness, S., **Raja, W.**, Erskine, A., & Njue, E. (2023, April 13-16). *Students' expressions of criticality and emotion in historically responsive math task contexts*. Paper presented at the Annual Meeting of the American Educational Research Association, Chicago, IL.

Altindis, N., & **Raja, W.** (2021). *Enacted Task Characteristics: Setting an Infrastructure for Students' Quantitative Reasoning.* Paper presented at the 43rd Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education (PME-NA 43), Philadelphia, PA.

Conference Proposal Reviewer

- Forty-fifth annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics
- Forty-third annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics

Conference Presentations

Raja, W. (2023, November 10). *How can we support students' learning in social justice mathematics classrooms?.* Presented at the Association of Mathematics Teachers of New York State (AMTNYS) 2023.

Raja, W. (2023). *Supporting Students Learning in Social Justice Mathematics Classrooms.* Presented at the School of Education Graduate Student Research Symposium. Syracuse University, Syracuse, NY.

Raja, W. (2023). *Teach to Support Student Learning in a Social Justice Context.* Presented at the Syracuse University Future Professoriate Program Annual Conference. Altmar, NY.

Raja, W. (2023). *Supporting Students Learning in Social Justice Mathematics Classrooms.* Presented at the 48th Annual New York Regional Graduate Mathematics Conference. Syracuse University, Syracuse, NY.

Raja, W., Caviness, S., & Odiwuor, B. (supervised by Fonger, N. L.) (October, 2022). *How do we analyze students' learning of mathematics through local social justice issues?* Presented at the Northeastern Conference on Research in Undergraduate Mathematics Education, Online.

Makumba, P., Omoze, H., & **Raja, W.** (2022, October 28). *How Can We Support Students to Engage in Mathematical Justification?* Presented at the Association of Mathematics Teachers of New York State (AMTNYS) 2022. https://sites.google.com/amtnys.org/72nd-annual-amtnys-conference/friday-october-28th?authuser=0

Raja, W., & Salim, Z. (2021, November 6). *Designing Tasks: Assessing Competencies Centered on Statistical Processes.* Presented at the Association of Mathematics Teachers of New York State (AMTNYS) 2021 Virtual Conference. https://sites.google.com/amtnys.org/amtnys2021/sat-nov-6

Altindis, N., & **Raja, W.** (2020, November 4). *Supporting Students' Meaningful Understanding of Functions.* Presented at the Association of Mathematics Teachers of New York State (AMTNYS) 2020 Virtual Conference. https://sites.google.com/amtnys.org/amtnys2020/wed-nov-4th

Poster Presentations

Raja, W. (December 2023). "*Social Justice Mathematics: Student Emotions and Task Design*". Poster presented at Annual Research Showcase, Syracuse, NY.

Raja, W., Njue, E., Fonger, N. L., & Caviness, S. (2022). "*What does math have to do with social justice?*". Poster presented at Syracuse University's Annual Mathematics Education Research Showcase, Syracuse, NY.

Njue, E., Fonger, N. L., Caviness, S., & **Raja, W**. (2022). *Social Justice Mathematics.* Poster presented at the Syracuse Office of Undergraduate Research and Creative Engagement Symposium, Syracuse, NY.

Published Books

Raja, W. A. (2017). *Geeky Maths 4*. Edugate Publications. https://issuu.com/edugate.com.pk/docs/math_4

Raja, W. A. (2017). *Geeky Maths 5*. Edugate Publications. https://issuu.com/edugate.com.pk/docs/math5

Awards and Honors

- The Arthur O. Eve Higher Education Opportunity Program (HEOP) and TRIOs Student Support Services (SSS) Ally Award (received in Spring 2024 for creating an inclusive climate that strengthens the retention to graduation efforts of HEOP and SSS students and supporting HEOP and SSS students to succeed in mathematics courses at Syracuse University)
- Certificate in University Teaching (received in Spring 2022 after completing the Future Professoriate Program)
- Outstanding Teaching Assistant (received from Syracuse University's Associate Provost for Graduate Studies and Dean in Spring 2022)
- Graduate Assistantship (Fall 2019-current)

Grants

2021

- School of Education Travel Grant ($400)
- School Of Education Graduate Student Council Travel Grant ($250)
- Graduate Student Organization Travel Grant ($400)
- Mathematics Department Travel Grant ($500)

2022

- School of Education Travel Grant ($400)
- Mathematics Department Travel Grant ($500)

2023

- Graduate Student Organization Travel Grant ($400)
- School Of Education Graduate Student Council Travel Grant ($200)
- Mathematics Department Travel Grant ($500)

Professional Development

- 'Child Protection for International Schools Level 2' by Educare Learning Ltd.
- Certified Positive Discipline Classroom Educator by Positive Discipline Association.
- 'Common Core Mathematics for all teachers' – Professional Learning Board
- 'Assessment strategies for the Common Core' – Professional Learning Board
- 'Understanding how students learn' – Based on Prof. Terry Doyle's workshop
- 'Project Based Learning Gold' – Ayesha Kasuri

Technical Skills

Course Management:

Proficient with Blackboard, Webwork, One Note, Microsoft Office, Zoom, Sapling Learning, Google Classroom, and Microsoft Teams

Software:

Proficient with IBM SPSS, R, STATA, Mplus, and Minitab for quantitative data analysis, MAXQDA and Nvivo for qualitative data analysis, and Mendeley and Zotero for managing research libraries.