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Making Mathematics Meaningful: How learning about local social injustices develops undergraduate students' identity, intellect, skill, and criticality

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Making Mathematics Meaningful

How learning about local social injustices develops undergraduate students' identity, intellect, skill, and criticality

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Abstract

This paper presents a study on applying Muhammad's (2020) historically responsive literacy (HRL) framework in mathematics education at the undergraduate level. The study analyzed data collected from historically responsive mathematics labs collaboratively designed by high school and college teachers in the Meaningful Mathematics Research Group. Through qualitative and quantitative data analyses, we determined that students found the labs meaningful because they could relate mathematics to a relevant and authentic context and/or feel a sense of geographic awareness or belonging. The results showed that this pedagogical shift enhanced students' understanding of mathematical concepts and their ability to express themselves through various identities, apply mathematical knowledge to social issues, and express awareness of injustices. The findings argue for curricular reforms that prioritize critical literacy and social justice in mathematics education at the undergraduate level.

Current mathematics education practices at the undergraduate level typically focus primarily on abstract concepts and procedures, often overlooking the importance of developing students' critical literacy. Approaches that prioritize students' development of skills and concepts alone can create a disconnect between students and the subject matter, as they fail to relate mathematical concepts to students' everyday lives (Pourdavood & Yan, 2022). Our research builds upon a rich history of social justice mathematics (Gutstein, 2006) and humanizing approaches (Gutiérrez, 2007). Integrating real-world contexts and social justice themes into mathematics instruction allows educators the potential to empower students to become more informed and empathetic members of their communities.

We apply Gholdy Muhammad's (2020) historically responsive literacy (HRL) framework as a model for designing mathematics tasks that emphasize critical literacy and social justice. Our research group, the Meaningful Mathematics Research Group at Syracuse University, designed culturally and historically responsive mathematics labs to support students to be more engaged in their local community while improving their precalculus core curriculum skills.

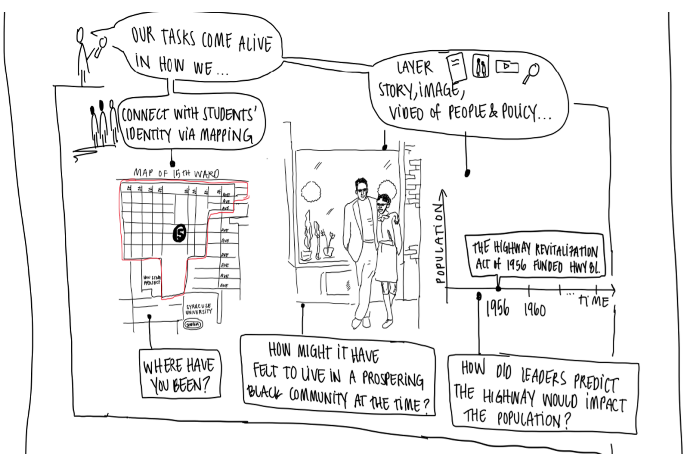
In this study, we analyzed and coded data collected from two problem-solving labs administered in the spring 2022 and fall 2022 semesters. We found that our introduction of historically responsive mathematics labs not only enhanced students' understanding of mathematical concepts, but also elicited students' expressions of a broad range of identities, including race, family, religion, community, or geographic location. The lab helped students apply their knowledge of mathematics to predict, explain, or otherwise express an understanding of a social issue or policy. Finally, students were also able to express awareness of specific and general injustices and/or power structures that shape communities and considered addressing them.

In this paper, we answer four questions through quantitative and qualitative analyses of the data collected in a problem-solving lab and survey implemented in two semesters. We ask: How meaningful is a historically responsive mathematics education lab to students? How do students link mathematical concepts to real-life experiences in meaningful ways? What makes the lab meaningful to the students? And how can educators take up the responsibility of enhancing students' inclusion and belonging? Through this research, we argue that a historically responsive approach can make mathematics learning more relevant and engaging for students, thereby improving their mathematical proficiency and their understanding of the world around them. Our findings suggest a need for curricular reforms that prioritize critical literacy and social justice in math instruction.

Muhammad's (2018, 2020) HRL model presents a four-layered equity framework for education. It is grounded in historical research on the intellectual success of African American communities throughout history and aims to restore excellence in literacy education. Muhammad's framework revolves around four pursuits: identity—helping young people to learn about themselves and others; skill—developing proficiencies across within academic disciplines; intellect—gaining knowledge and becoming smarter about topics and issues; and criticality—learning and developing the ability to read texts (including print and nonprint texts) as well as to name and understand issues of power, (in)equity, and (anti-)oppression.

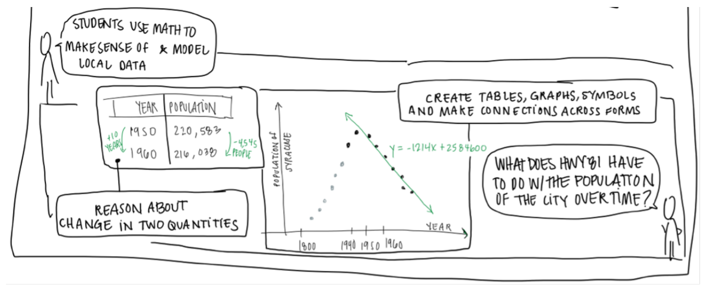
The study focused on problem-solving labs that were implemented in precalculus courses in spring 2022 and fall 2022. The labs focused on integrating real-world contexts and social justice themes into math instruction.

Figure I - *Fonger, 2023*



Some of the local social justice themes included integrated discussions about Highway I-81, redlining, the 15th Ward (Figure 1), population decline (Figure 2), and lead poisoning (Fonger, n.d.). These labs were historically responsive in how they focused on local, social, and environmental issues. They aimed at engaging students in their local community while improving their proficiency in core precalculus skills. This paper focuses on the Highway I-81 lab, which explains the highway's history and context. It analyzes data from the spring 2022 and Fall 2022 trials.

Figure II - *Fonger, 2023a*



In the I-81 lab, students watched videos, read articles, and looked at interactive maps, all of which were designed to help them learn about the historical context of the highway. They were asked to predict the effect of the highway construction on the city population. The students were then introduced to mathematical concepts such as identifying trends in data, reading scatterplots, and using the point-slope form of a linear equation. To help them apply their understanding of these concepts, they were given a set of data about Syracuse's population from 1850 to 1960 and asked to identify the independent and dependent variables. This would predict the city's population after 1960, create a line of best fit for the data, and complete other related mathematical activities. The highway lab was therefore able to integrate learning about these mathematical concepts into a social justice lesson about the history of I-81. Students were also asked survey questions before, during, and after the lab, which were designed to encourage them to think critically about what they learned and to gauge the effectiveness of the lab.

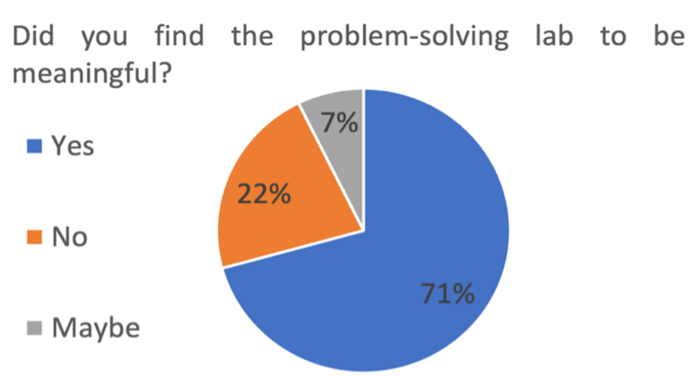
We collected data from students' lab responses and post-lab surveys and used a mixed-methods approach in applying both quantitative and qualitative data analysis techniques. Quantitative data were analyzed using statistical methods like regression and correlation analyses to identify trends and patterns. Qualitative data were sorted and coded using systematic thematic analyses (Braun & Clarke, 2006) to establish codes. We then analyzed student responses to understand themes in students' perceptions and experiences. The results shared in this paper draw on the work of a larger study as reported in Fonger, Raja, Odiwuor, Caviness (in preparation).

For the thematic analyses, we defined four codes from the four goals in Muhammad's (2020) framework and used them to analyze the data. We defined *identity* as students learning about themselves or others in the social context of the lesson. *Skill* is students' demonstration of mathematical skills in responding to questions (e.g., students can read, identify, and interpret information from a scatterplot). *Intellect* is described as students applying mathematics to quantify a social or racial justice issue. *Criticality* is students expressing awareness of a specific or general injustice (e.g., racism, white flight) and/or power structures that shape communities and considering addressing these injustices.

In addition, we defined two codes that helped us understand the reasons students found the labs to be meaningful. The first one is *locality-identity* (Caviness, Fonger, et al., 2023), used when students place themselves in the lesson through a map of the city, names of landmarks they know, or descriptions of lived experiences. Students may identify as being "from" where the lesson took place. For instance, when asked about why the lab was meaningful, one of the students answered: "It was meaningful because Syracuse is now my home and I need to be informed on what goes on around me." The second code is *relevant and authentic* (Caviness, Fonger, et al., 2023), used when students express perceiving the lab as relatable and applicable to real-life contexts. When a student was describing how the lab was meaningful to them, they wrote: "[I] really enjoyed being able to see a real world connection to the math I was doing. It helped [me] better understand the concepts and see real world uses for the things we are learning in class." Another student said: "It gave students a chance to analyze real-life data and not made up numbers from a textbook." The study's results provide strong evidence that the historically responsive mathematics labs were meaningful to students, in that students were able to form connections between mathematical concepts, real-life experiences, and their sense of locality identity.

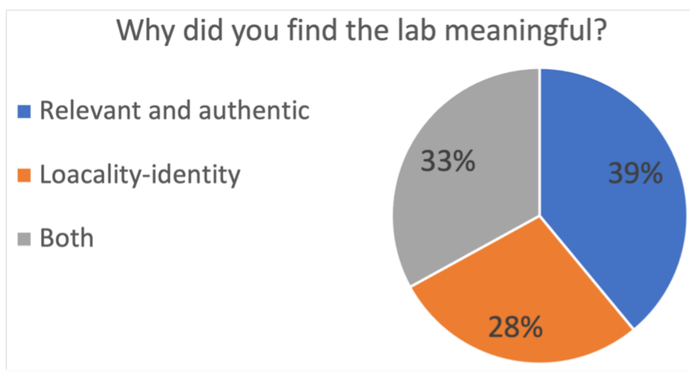
To understand the impact of the lab experience on students, a post-lab survey was conducted. Students were specifically asked the question, 'Did you find the problem-solving lab to be meaningful? Explain.' The open-ended responses to this question were then analyzed qualitatively and categorized as responses of "Yes," "No," and "Maybe." Of the 41 responses analyzed, 71% of the students who responded to the question indicated that they found the lab to be meaningful (Figure 3).

Figure III



Further analysis of the student responses that were coded as "Yes" showed that 39% expressed that the lab was meaningful due to its relevance and authenticity, 28% conveyed that they were able to establish locality-identity connections with the data presented in the lab, and 33% found the lab to be meaningful due to the presence of both elements (Figure 4).

Figure IV



We surveyed students about their experiences in the problem-solving lab, asking them to rate their level of agreement or disagreement with various statements on a scale of 1 to 5. A rating of 5 means "strongly agree," while a rating of 1 means "strongly disagree." The calculated medians suggest that after completing the lab, students were able to model local data with a linear function, identify racial inequities for Syracuse residents, feel a sense of righteous indignation about people's homes and businesses being destroyed, and deepen their understanding of how math can be applied in city planning.

We identified significant correlations with coefficients exceeding 0.69 between three pairs of questions (see Appendix for a full list of the questions). The correlation between Q2 and Q7 was 0.72, suggesting that the problem-solving lab was effective in helping students model local data with a linear function and appreciate the connection between math and problem-solving skills. The correlation between Q11 and Q12 was 0.71, indicating that the lab successfully integrated socio-political issues—such as the negative impact of highway construction on a prospering Black community in Syracuse—into students' perceptions. The correlation between Q14 and Q15 was 0.86, demonstrating that the lab enabled students to apply mathematical knowledge, like using the slope-intercept form of a linear equation, to real-world applications, such as city planning.

The findings suggest that integrating real-world contexts and social justice themes into math instruction can make math more relevant and engaging for students. The findings support others' arguments for a shift in mathematics critical literacy and social justice (e.g., Gutstein, 2006; Gutiérrez, 2007). The results suggest a need for more culturally and historically informed math education and show that educators can take up the responsibility of enhancing students' inclusion and belonging by attending to their identities and the identities of others, allowing them to better analyze and understand these issues.

This work represents a collaborative effort of the Meaningful Mathematics Research Group at Syracuse University led by Associate Professor Nicole L. Fonger. Team members during Summer 2023 include (alphabetical order by last name): Emanuel Boutros, Stephen Caviness, Nicole Fonger, Sankalp Gautam, Winnie Naggar, Karley Voyias, Qiong (Mars) Wu, and Hanyi Xu. Our work is informed by collaborations with the Antiracist Algebra Project and Engaged Communities Team including Lauren Ashby, Ken Keech, Jonnell Robinson, and Betty Routhouska. We are grateful to the SOURCE for student funding, the Mathematics Department for resource support, and the Engaged Humanities Network for grant funding.

Appendix

Question 1: The Problem-Solving Lab supported me to read and interpret a scatter plot relating two quantities (Syracuse population, time since 1850).

Results. Mean: 4.52; mode: 5; median: 5.

Question 2: The Problem-Solving Lab supported me to model local data with a linear function and interpret the meaning of the data with respect to the context.

Results. Mean: 4.62; mode: 5; median: 5.

Question 3: The Problem-Solving Lab supported me to learn about possible reasons the Syracuse population declined after the year 1950.

Results. Mean: 4.72; mode: 5; median: 5.

Question 4: The Problem-Solving Lab supported me to believe that the construction of highway 81 is an important issue for Syracuse residents.

Results. Mean: 4.72; mode: 5; median: 5.

Question 5: The Problem-Solving Lab supported me to affect change on social justice issues in Syracuse.

Results. Mean: 4.26; mode: 5; median: 5.

Question 6: The Problem-Solving Lab supported me to identify racial inequities for Syracuse residents.

Results. Mean: 4.64; mode: 5; median: 5.

Question 7: The Problem-Solving Lab supported me to appreciate the connection between math and problem-solving skills.

Results. Mean: 4.36; mode: 5; median: 5.

Question 8: Think about your overall experience completing the Problem-Solving Lab as part of MAT 194 in Spring 2023. Rate the following: The Problem-Solving Lab is relevant to my life experiences.

Results. Mean: 3.76; mode: 5; median: 4.

Question 9: Think about your overall experience completing the Problem-Solving Lab as part of MAT 194 in Spring 2023. Rate the following: The Problem-Solving Lab is relevant to what I learn in math class.

Results. Mean: 4.17; mode: 5; median: 4.5.

Question 10: Rate how you think the Problem-Solving Lab inspired a sense of joy or safety in a community that is a refuge from discrimination.

Results. Mean: 3.71; mode: 4; median: 4.

Question 11: Rate how you think the Problem-Solving Lab inspired a sense of righteous indignation about people's homes and businesses being destroyed.

Results. Mean: 4.17; mode: 5; median: 4.

Question 12: Rate how you think the Problem-solving lab supported me to understand how the building of a highway negatively impacted a prospering Black community in Syracuse.

Results. Mean: 4.59; mode: 5; median: 5.

Question 13: Rate how you think the Problem-Solving Lab supported me to connect math to where I have been, my racial identity, and the history of the city I live in and go to school in.

Results. Mean: 4.17; mode: 5; median: 4.

Question 14: Rate how you think the Problem-Solving Lab supported me to learn to use slope-intercept form of a linear equation and make lines of best fit to make predictions about trends in population data over time.

Results. Mean: 4.465517241; mode: 5; median: 5.

Question 15: Rate how you think the Problem-Solving Lab supported me to know more about how math can be used to make predictions in city planning and how some predictions may be incorrect.

Results. Mean: 4.413793103; mode: 5; median: 5.

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