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# Insights into Pothole Damage: Exploring Culturally Responsive Mathematical Modeling

**William Reid Carlisle[1] · Hyunyi Jung[2,5] · Megan H. Wickstrom[3] · Kayla Sutcliffe[2] · Hee-jeong Kim[4]**

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## Abstract

Although culturally responsive mathematics teaching is important, post-secondary education for preservice teachers (PTs) does not typically lead to learning opportunities for them to use mathematics to recognize the roles of social agents. To address this issue, we created a culturally responsive mathematical modeling task in which we invited PTs to use diverse approaches to create an action plan for the handling of local pothole data and maintenance. This study explores the approaches that PTs take when generating solutions to solve a culturally responsive mathematical modeling task and to investigate the perceptions of preservice teachers towards the task. The study involved 41 PTs, most of whom had no prior experience with mathematical modeling before participating in the task. PTs compared and inspected the documented data and noticed problems, such as a large economic disparity in the city. The PTs drafted solutions and shared their findings and suggestions in a proposal to the City's Public Works Department. The proposals reflected different approaches, which helped the PTs understand the large income disparity and inequities certain neighborhoods in the city experience and provided recommendations for the city to address these issues. The creation of a culturally responsive mathematical modeling task provided an opportunity for PTs to engage in critical thinking and problem-solving while using diverse approaches to address a local social justice issue. This study provides insights into effective strategies for promoting socially responsible mathematics education in teacher preparation programs.

**Keywords** Culturally responsive teaching · Modeling · Preservice teachers · Task design

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Extended author information available on the last page of the article

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Mathematics education researchers highlight the importance of all students having opportunities to learn about mathematical modeling (Blum, 2015; Blum & Borromeo Ferri, 2009; Doerr & English, 2006; Jung & Brady, 2023). Mathematical modeling can be described as a process of interpreting real-world problem-solving context, using mathematics to solve the problem, and contextualizing the solution into the real-world (English et al., 2005; Greer, 1997). It requires and develops critical thinking, social skills, and background knowledge as learners collaboratively create strategies for their solutions (Chan, 2008; Doerr & English, 2003; English & Watters, 2004). When engaging in mathematical modeling, learners not only draw on their mathematical knowledge but also cultural knowledge and experiences. This process allows the connection between mathematical modeling and culturally responsive teaching (Jung & Wickstrom, 2022).

Culturally responsive teaching builds on Ladson-Billings' (1995) work on culturally relevant pedagogy. She called for educating students to achieve academically, build cultural competence, and examine and critique unfair social order. In 2014, Ladson-Billings pondered the evolution of her culturally relevant pedagogy, underscoring the importance of a dynamic comprehension of culture and an instructional approach that overtly addressed issues of equity and justice. She also stressed the capacity to extend learning beyond the classroom, utilizing knowledge to identify, analyze and address real-world problems. By integrating real-world problem-solving with her theories, culturally responsive teaching provides opportunities to examine and tackle local and large-scale social issues through a mathematical lens (Ingen et al., 2018). Teacher educators recognize the need for substantial efforts to equip teachers with appropriate learning experiences and resources to engage students in understanding social issues through mathematics (e.g., Anhalt et al., 2017; Jung & Magiera, 2021; Jung & Wickstrom, 2023; Tate, 1994; Turner & Strawhun, 2007). In order to prepare teachers to enact culturally responsive modeling problems, it is important for them to experience them as learners (Aguirre et al., 2019; Jung & Wickstrom, 2023),

Built on these studies, we created a culturally responsive mathematical modeling task that engages preservice teachers in using mathematical and personal perspectives to understand and critique a social justice issue. The task at hand exemplifies how mathematics can be integrated into understanding an issue with social repercussions and promoting agency in fixing such an issue. Specifically, our research questions are: "What approaches do preservice teachers take when they generate a solution to solve a culturally responsive mathematical modeling problem?" and "How do preservice teachers experience a culturally responsive mathematical modeling problem?".

## Relevant Literature

The theoretical background for our study has two strands: culturally responsive teaching followed by social justice in mathematics education, and mathematical modeling connected to culturally responsive teaching. Thus, in this section, we describe the theoretical background of each strand.

### Connecting Mathematics Teaching to Culturally Relevant Pedagogy

Development of terminology and a more sociopolitical take on teaching and learning mathematics exist as part of the resource pedagogy movement that grew to oppose the deficit views towards students of color held in the mid twentieth century. Resource pedagogies hold that the "languages, literacies and cultural ways of being of students of color" have equal weight to the "ways demanded and legitimated in school teaching" rather than viewing these traits as obstacles to be overcome (Paris, 2012).

These traits were termed funds of knowledge by Moll and Gonzalez (1994), with that framework and its implications for teaching innovations. Civil (2016) emphasized the concept of knowledge valorization, the relational valuing of different practices, as it applied to nondominant cultures. She notes that students hold a notion of different mathematics, with the mathematics particular to cultural groups and everyday situations holding little value in the mathematics students are expected to accomplish in school (Civil, 2016).

Like the shifting and evolving nature of the cultural funds of knowledge that educators can draw from, the concept of a culturally responsive pedagogy represents an evolution, or building upon, of previous work. The influential contribution by Ladson-Billings (1995) to the field of culturally relevant pedagogy deserves recognition for her urging to cultivate students capable of academic accomplishment, exhibiting cultural proficiency, and fostering the ability to comprehend and analyze the prevailing social structure. Her work demands that teaching be not only relevant to the culturally-situated identities and everyday situations of learners, but that it also helps them to strengthen their cultural ties and critically assess their situations.

The concept that forms the framework for this paper is the somewhat broader notion of culturally responsive teaching developed by Geneva Gay. In her 2018 work, Gay summarized this teaching methodology to utilizing the cultural insights, previous life encounters, points of reference, and distinctive performance approaches of students from diverse backgrounds to increase the relevance of learning interactions for them. Notions of cultural relevance and responsiveness are almost interchangeable in most research, even in their own definitions, but what is important is that teaching in this way is ultimately informed by a concern for sustainability–the fostering of cultural pluralism and maintenance of students' cultural ways of being (Paris, 2012).

It is important, in taking on culturally responsive teaching, for current and preservice mathematics instructors to assess and critique their beliefs and pedagogies. In their work with preservice teachers, Aguirre et al. (2012) found that 90% of their participants felt ideologically and pedagogically receptive toward connecting mathematics lessons to students' funds of knowledge. However, there existed some reservations, resistance, and perceived challenges to doing this and integrating language support and social justice. A result of particular note is that preservice teachers exposed to community mathematics experiences expressed more comfort with connecting mathematics to social justice and picturing how they could make a pedagogical shift towards culturally relevant (Aguirre et al., 2012). Furthermore, a study with preservice mathematics teachers found that reflecting and revising a mathematics task gave them the opportunity to interact with the concepts of culturally relevant

pedagogy and reservoirs of knowledge throughout the semester, equipping them with a practical approach that they can apply in their forthcoming teaching endeavors (Gallivan, 2017).

## Social Justice Pedagogy and Culturally Responsive Teaching in Mathematics Education

As mentioned prior, culturally responsive pedagogy was developed as a part of a turn of perspective on teaching and learning in the late twentieth century. Gutiérrez (2013) coined the term "sociopolitical turn" in mathematics education to encapsulate this shift and the many perspectives involved, including critical mathematics education, post-structuralism and novel ideas of identity and power. Social justice pedagogy, according to Leonard et al. (2010), can be used for application within mathematics classrooms to assist students in comprehending and employing mathematical concepts to address questions that could have a positive impact on their lives and the well-being of their communities. Social justice pedagogy can be reached by culturally relevant practices, as shown in a graduate level teacher education study by Leonard and Evans (2008). Similar to the calls to action made by Ladson-Billings (2014), and Gay (2018), Gutstein (2006) emphasizes the importance of students delving into the examination and assessment of injustice, and actively questioning oppressive systems and behaviors, a skill of engaging in mathematical literacy for critical understanding and expression.

Gonzalez (2009) identifies four key components to teaching mathematics for social justice. The first of these is ensuring that every learner has the opportunity to receive excellent mathematics education. This opportunity is pivotal as it equips them with the necessary literacy to comprehend societal dynamics. However, a significant disparity exists in attaining such high-caliber mathematical instruction. The second and third components, centering curriculum around diverse students' experiences and the critical understanding of social issues, tie well into the tenets of culturally responsive pedagogy (p. 25). The fourth component highlights how mathematics lessons should be used towards "liberation from oppression" (Gutstein, 2006, p. 22). Mathematics here exists as a lens for viewing topics of social concern and as an avenue by which students may address or combat inequity.

Mathematics teaching has been well shown to be capable of highlighting inequities and motivating action, but the subject and STEM learning generally does not accomplish this. Multiple studies indicate that the study of STEM does not promote or foster the development of social agency in students, particularly at the post secondary level. Garibay (2015) noted that many do not see their realm of study, or career path for that matter, as an object tied to social responsibility (p. 624). We know, however, from research produced by Ingen et al. (2018), that STEM learning and culturally responsive teaching have great synergy and offer opportunities for local and large-scale social issues to be looked upon and addressed with a STEM lens. In work with graduate education students, Leonard and Evans (2008) noted the importance for novice teachers to see social justice pedagogy in practice. Likewise, teacher educators and mathematics education researchers point out that social justice pedagogy and culturally responsive methods can help students see STEM,

mathematics in particular, as an avenue for social change, and exposure to these methodologies enables teachers to implement them to students' benefit.

## Conceptual Framework: Mathematical Modeling and Its Connection to Sociocritical Lens

Mathematical modeling is a process of utilizing mathematics to interpret and analyze authentic, real-life situations to improve decision-making in everyday life (Bliss et al., 2014; Lesh & Doerr, 2003). It requires (a) understanding the problem context, (b) making assumptions, (c) analyzing and working mathematically, and (d) interpreting and validating results to make an informed decision (Bliss et al., 2014). As such, the process can be said to be cyclical, offering multiple opportunities for choice-making, refinement, and engagement for a larger group of students (Aguirre et al., 2019, p. 8). Teaching mathematical modeling in K-16 classrooms is necessary to increase students' intrinsic motivation, cultivate a positive attitude towards mathematics in general, and make the connection between mathematics and students' daily lives (Arseven, 2015). Modeling has come to be imperative in the K-16 classroom, as Burkhardt (2016) has asserted that society now needs critical thinkers, who can use their mathematics to positively contribute to their communities.

Researchers discuss the importance of teachers having enough time to learn about mathematical modeling in order for them to implement it in practice (Bal & Doganay, 2014; Cetinkaya et al., 2016; Doerr, 2007; Geiger et al., 2022; Kuntze, 2011; Ng, 2013; Tidwell et al., 2023; Türker et al., 2010). Both preservice and in-service teachers are rather unsure about their content and pedagogical knowledge regarding the mathematical modeling cycle and task design and hold certain fears and apprehensions about the "incompatibility of modeling tasks with the goal of mathematical exactness" (Kuntze, 2011, p. 286). Due to their inexperience with understanding potential approaches to learning and teaching mathematics through modeling, teachers are also unsure of how to adapt it within their classrooms (Geiger et al., 2022). Additionally, many teachers do not have opportunities to learn about how mathematical modeling addresses sociocritical issues and how modeling can be a powerful tool to understand and respond to issues in our world.

To address these concerns, teacher educators have designed and/or implemented new mathematical modeling tasks around social justice issues and collaborated with teachers to learn about the modeling process involved in tasks (e.g., Aguirre et al., 2019; Flavin & Hwang, 2024; Suh et al., 2023). Jung and Magiera (2021) provided three criteria to pose a social justice oriented mathematical modeling problem which included the following: 1) the problem is situated in a context that addresses micro- and macro-level social justice issues, 2) the problem requires the development of a mathematical model, and 3) investigating the problem leads to results that can be shared with a broader audience that cares about the issue. In their work on applying a modeling task around the Flint water crisis, Aguirre and colleagues invited the teachers to design mathematical models to address the water crisis problem that happened in Flint. They found that teachers' impact could be demonstrated both in their models and in their reflection on the task. Teachers' work demonstrated distinct approaches to the problem, based on

their assumptions and priorities, as well as their choice of mathematical approaches to address the issues. The teachers engaged in the modeling envisioned this task and others of the like to have great benefits for students in its "relevance and real-world linkages of math to investigate current and community-based events" (p. 15).

Similarly, Jung and Wickstrom (2023) described how teachers utilize their mathematical knowledge and personal resources to engage in modeling with a sociocritical perspective. They designed the school funding modeling task, which invited teachers to develop mathematical models for allocating school funding, based on actual data from various schools. The authors found that teachers initiated and refined a range of mathematical models that bridged the gap between mathematical concepts and social issues. By drawing on their personal experiences, the teachers demonstrated critical awareness in analyzing data and making decisions about the allocation of school funds.

Indeed, both the Flint water crisis and School Funding tasks embody the potential of implementing culturally responsive teaching through a mathematical modeling problem. As these are methodologies that many teachers appear open to, even if unconfident in their ability to implement, exposure to and practice in the cycle of mathematical modeling, with reflection on the cultural relevance of encountered tasks, offers a valuable exercise for teachers. Providing opportunities for teachers to learn about modeling through sociocritical lenses as modelers and to reflect on their learning can serve as the first step towards integrating modeling and culturally responsive problems into practice.

## Background and Methods

This study is part of a larger NSF-funded project that supports the design, implementation, and refinement of mathematical modeling modules in teacher preparation programs. The second author (Jung) served as a coordinator of the elementary mathematics education program at a university located in the Southeastern region of the U.S. where she designed culturally responsive mathematical modeling tasks and collaborated with adjunct faculty and graduate students to incorporate culturally sustaining pedagogy (Paris, 2012) and mathematical modeling into the courses that she supervised and taught. The first author took a graduate-level Culturally Sustaining STEM Education course taught by Jung and initiated the Pothole Damage Task as a part of the course assignment. After the course ended, the first, second, and third authors met to refine further the task to be integrated into the elementary content and methods courses. The first and second authors co-taught the Pothole Damage task using "equity-based mathematics teaching practices" (Aguirre et al., 2013, p. 43), which involved high cognitive demand tasks that support PTs' problem solving through modeling, positioned their various mathematical competencies, affirmed their mathematical identities through positive and collaborative learning environments, valued multiple mathematical contributions, and drew from their multiple sources of experiences to connect them to their mathematical learning. Participants in this study include 41 preservice elementary teachers (PTs) in the course; Most participants did not have experiences learning about mathematical modeling prior to engaging in this task. In the two sections of the course that combined both elementary

content and methods, the PTs worked on the Pothole Damage Task in teams of two or three, resulting in 14 groups total. In this section below, we describe the nature of the Pothole Damage Task and the data collection and analysis processes.

### The Pothole Damage Task

The task introduced to participants presents data local to a city in the Southeastern region of the U.S. for participants to interpret. They are first given a map of the city with pins over any potholes that were reported in the last year, color-coded based on the response time. After developing some assumptions and critiques about the map and data presented, students are given a spreadsheet that conveys the median income and racial demographics of each neighborhood in the city, labeled and outlined on the map. Between the map and the spreadsheet, participants form groups, choose neighborhoods that they want to look closer at based on a number of pothole reports or the demographics therein, and fill out a table to organize the number of reports, the city's response times and the proportions of different races (Asian, Black, White, Latinx, mixed and other) in each neighborhood. After sharing their findings and suggesting different causes, participant groups get to work on a proposed solution to the problem.

The pothole damage task takes inspiration from a 2013 Los Angeles Times study on road safety ratings in several neighborhoods and districts of the city. Their study highlights the city's struggle with keeping up with the widespread problem, opting to address easier-to-fix roads before those with serious damage, and their struggles with representing the issue in an equitable light. In this task, PTs are placed in the position of data analyst for an activism group and asked to draft a proposal to a city's Public Works Department for the better handling of local pothole data and maintenance. The mathematical and modeling goals of the task included: (a) making sense of data that shows pothole damages across neighborhoods, (b) analyzing maps and numerical data sets (e.g., locations, response times to pothole issues, socioeconomic and demographic information) (c) using mathematical ideas, such as fractions, percents, and ratios, to compare the attributes of the four neighborhoods, and (d) communicating an informed decision based on the analysis of data and mathematical evidence. We attempted to emphasize both the rich mathematical content (Aguirre, 2009) while maintaining a discussion on the social justice issues that have implications for different communities based on income and racial demographics in various neighborhoods. For more information about the Pothole Damage Task, see Appendix A.

Being confronted with data for neighborhoods with various road hazards and income levels incorporates the frames of reference and prior experiences that are cornerstones to culturally responsive teaching as defined in the work by Gay (2018). Furthermore, the task draws from students' identities through family and community experiences–what may be a small bump in an otherwise well-maintained road in someone's neighborhood may be the cause of expensive automobile repairs or an obstacle to be avoided in another's. Students' ethnicity, socioeconomic status, values and other elements of identity prized in work with CRT (Ingen et al., 2018, p. 6) is called upon as well in the completion of the final product of the task; following the analysis of data by students, they are to take action at the level they feel most comfortable.

### Data Collection and Analysis

As we implemented the task, we took field notes about our instructional decisions, collected students' written work on the task, and gathered their journal reflections. After reviewing these data sources, we further analyzed students' written work and their journal reflections using constant comparison methods (Glaser, 1965). The first phase of analysis involved reviewing and summarizing each team's written work, our notes, and journal reflections through our conceptual framework described above. The first two authors discussed a sample of PTs' written work and made a consensus on the structure and content of each summary. A summary of the rest of the PTs' models and approaches was documented to be aligned with the first research question (i.e., What approaches do preservice teachers take when they generate a solution to solve a culturally responsive mathematical modeling problem?). We then grouped similar approaches to devise emerging categories of main approaches that belong to multiple examples. We then further analyzed the data based on PTs' action plans in response to the pothole damage task, which were formed from a review of relevant data on different neighborhoods' demographics, population, income, number of potholes, and wait time. This constant comparison method process (Glaser, 1965) led to the five emergent categories of approaches: (a) an accessibility approach; (b) an income-based approach; (c) a dissemination approach; (d) an analytics approach; and (e) an alternative reporting approach. In each approach, relevant modeling processes (c.f., Bliss et al., 2014; Author, Year) emerged and were noted, which include (a) understanding the context with critical eyes, (b) making relevant assumptions, (c) analyzing and working mathematically, and (d) identifying a descriptive, sociocritical conclusion. In our results section, we described each of these approaches with specific examples.

We also analyzed PTs' journal reflections by reviewing and summarizing each of 41 individually written reflections. The first two authors discussed a sample of PTs' journal reflections and made a consensus on the structure and content of each summary (aligned with the second research question: "How do preservice teachers perceive a culturally responsive mathematical modeling problem?"). After summarizing all the reflections, we reviewed and grouped them by similar themes of key takeaways that PTs mentioned and their reasons for why the takeaways are important to them. This process led to the common themes of their perspectives, which included (a) cultivating mathematical literacy; (b) building awareness of social justice; and (c) learning about new ways to teach culturally responsive mathematical tasks. We illustrated each of these perspectives with quotes from PTs' work in the next section.

## Results

Overall, all groups acknowledged the importance of inspecting and comparing the documented data. Accordingly, PTs noticed problems based on the data, specifically identifying a large economic disparity in the city. In order to share findings and suggestions, participant groups drafted solutions in a proposal to the City's Public Works Department for the better handling of local pothole data and maintenance.

Upon examination of the PT-generated action plans, social justice issues were well represented along with the integration of mathematical content.

We found that PTs used five diverse but related approaches while engaged in the pothole task: an accessibility approach, an income-based approach, a dissemination approach, an analytics approach, and an alternative reporting approach. Some slight variations occurred, but each team utilized two to four approaches to create their action plan, as several of them are connected. For example, several teams indicated that there is an income discrepancy in the city and that it may cause internet accessibility issues for certain communities, which combines both the *income-based* and the *accessibility* approach. Table 1 below shows an interplay between each of the five approaches that were used in combination by some of the PT teams.

Most teams utilized an *income-based* approach. In understanding the problem context, PTs focused on the pothole data on the map and income in each area, looking for potential relevance between the pothole report and the average income in the area [understanding the context with critical eyes]. They assumed there might be relations between income data and the pothole report data [making relevant assumptions]. They calculated the number of pothole reports in each area and made a table to organize the data [analyzing and working mathematically]. Based on their analysis, they concluded that middle-income communities had the highest reported amount of potholes and that the lowest income communities' potholes are likely underreported due to other factors, such as using public transportation more often than other communities due to their lack of income [identifying a descriptive, sociocritical conclusion] (Team 4A). Similarly, Team 2A stated that "higher income areas do not get potholes as often since the maintenance is more consistent and also there are less people living in the area." Team 2B "assumed that there is less chance of car ownership in low-income areas". Since 11 of the 14 groups used this approach, income was the data point that most PTs focused on and inspected when looking at pothole report issues. As shown in their statements and analyses, the processes of documenting and analyzing data helped them investigate the large income disparity and inequities certain neighborhoods in the city experience, and their connections to pothole reports.

Many teams' proposals reflected an *accessibility* approach, which specifically identified the inability to obtain reliable internet access as a reason potholes are not reported in certain neighborhoods. For instance, Team 1A looked into the pothole report data with a critical perspective by questioning whether certain neighborhoods have access to report the pothole problems [understanding the context with critical eyes]. They expressed, "in higher income neighborhoods, there have generally been more reports of potholes, as they may have more access to the internet to report these potholes" [making relevant assumptions]. The team made a table organizing the pothole reports with the neighborhood data, calculating the instances from the map [analyzing and working mathematically]. Based on the interpretations of the data, PTs inferred what possibly could cause these differences and offered suggestions that the city could implement [identifying a descriptive, sociocritical conclusion]. Similarly, Team 1B shared "we believe that potholes could be handled better if the process of reporting them is more accessible. For example, having a phone line where people just call the number and can report it that way. This would assist those who do not have access to the internet and it makes the process more efficient because people can

**Table 1** Five approaches used by PT teams

| Approaches | Income-based | Accessibility | Alternative reporting | Analytics | Dissemination |
|---|---|---|---|---|---|
| PT Teams | 1A, 2A, 3A, 4A, 5A, 6A, 7A, 1B, 2B, 6B, 7B | 1A, 2A, 5A, 6A, 7A, 1B, 2B, 5B, 7B | 7A, 1B, 2B, 4B, 5B, 6B | 5A, 1B, 2B, 4B, 6B | 4A, 7A |

call as soon as they see them and while they are on the road." Nearly all the proposals that used this approach also mentioned low income as a barrier to accessing reporting methods, which shows a connection was made between income and accessibility.

Half of the teams' proposals used an *alternative reporting* approach, which recognized the need for cities to implement different reporting methods to make it easier for citizens to report potholes, rather than relying solely on internet access, for example, which coincides with both the income-based and accessibility approach. For instance, when looking into the pothole situation, Team 4B noted little public knowledge on methods to report potholes [understanding the context with critical eyes]. They assumed that people might not report potholes because of the reporting systems [making relevant assumptions]. As they calculated the number of pothole reports and organized map data, they noticed that "low-income neighborhoods demonstrate a lack of potholes and civilian reporting" [analyzing and working mathematically]. They concluded, "With low-income neighborhoods, there is an increased likelihood of low internet accessibility. To combat this obstacle, we propose that the city provide several variations of pothole reporting for residents. This could include reports via phone calls, in-person assemblies, etc." [identifying a descriptive, sociocritical conclusion]. This interpretation combined the income approach, the accessibility approach, and the alternative reporting approach, which reveals a realization that most of these factors are interrelated. The teams using this approach interpreted the data and made recommendations using a social justice and equity lens, since it was clear to them that many communities do not have internet, something that is so easily accessed in other communities.

The fourth approach reflected in PTs' action plans was an *analytics* approach, which concluded that the city officials should survey neighborhoods' road quality themselves to prioritize which communities should be helped first. In interpreting the pothole situation, Team 1B wondered whether the city officials are informed by the data they see [understanding the context with critical eyes]. They assumed if the city officials were more proactive, pothole problems could have been addressed more quickly than what was shown on the maps [making relevant assumptions]. They looked into the population densities and calculated the number of pothole reports occurring in each area [analyzing and working mathematically]. The team concluded that "the city can acquire this data by doing research on the areas to find population densities and the historical aspect of the roads. Road usage can be found by observing the roads over a period of time. It should be used to predict where possible potholes could emerge and how to avoid them" [identifying a descriptive, sociocritical conclusion]. This approach recognizes that the city has a duty to fulfill, which is to aid all its residents, regardless of race or income, which again, addresses the task through a social justice and equity perspective.

Only two teams used the last approach, a *dissemination* approach. PTs found the need to increase efforts to spread the word about reporting methods and inform the citizens that it exists, since some communities might be unaware that there is even a need to report potholes. For instance, Team 7A noticed that the reporting methods were not only new to people they observed in the problem situation, but also new to themselves [understanding the context with critical eyes]. They assumed that if more people knew about the reporting methods, then the pothole problems could have been solved more effectively [making relevant assumptions]. As they looked into and analyzed the data, the team noticed that certain neighborhoods did not report pothole problems even though there were many potholes in those areas [analyzing and working mathematically]. They shared that it would be important to "use social media, flyers, emails, radio, newspaper to spread information on how to report potholes. This information can be used to inform citizens about self-reporting, and can also emphasize their importance in the community" [identifying a descriptive, sociocritical conclusion]. These teams identified the need to fairly distribute information, which directed the students toward finding and acting on issues of inequity and injustice using their recommendations. Offering multiple solutions to disseminate pertinent information demonstrates the PTs' cognizance of the unfairness and discrimination that occurs in the city.

It is evident that the use of distinct approaches in response to the pothole damage task fostered the development of equity through multiple lenses by urging a need for action from the city. Although the PTs perceived a culturally responsive mathematical modeling task in different ways, across solutions social justice issues were successfully addressed and real-world assumptions and decisions were made.

## Evidence of the Impact of the Activity: from Preservice Teachers' Journal Reflections

Analyzing participants' reflections to the questions "what are the key takeaways from this task?" and "why are these takeaways important?" revealed three themes suggesting that the PTs involved deepened their knowledge of culturally responsive teaching. Table 2 below summarizes the themes and the number of individual PTs whose reflections aligned with them.

First, over half (26 out of 41) of PTs agreed that qualities of the pothole damage task helped to cultivate mathematical literacy as they gathered the skills to use and interpret mathematics in several contexts, particularly practical contexts. The participants cited that the task allowed them to "analyze the data by calculating percentages to help us come to a decision." The practice with skills surrounding statistical analysis, a necessary skill for aware and active citizenship in the modern day, proved to be very valued by PTs, with one mentioning "it teaches us how to do percentages and understand data as a whole, which is something that will be important in our everyday lives." Furthermore, 13 PTs suggested that the pothole damage task brought with it a better appreciation for the mathematics of everyday life. Many appreciated the use of real data, one recognizing that "math is used in everyday life and some people use these numbers to come up with solutions that can be beneficial to everybody." This cognizance of the processes of modern life that are built on mathematics and

**Table 2** Themes emergent from individual PTs' journal reflections on the task and its implementations

| Themes emergent from PTs' journal reflections | # of PTs |
|---|---|
| PTs as learners | |
| Engaging in the task aided them in cultivating mathematical literacy as they gathered the skills to use and interpret mathematics in contexts | 26 |
| The task instilled a greater appreciation for the mathematics inherent in everyday life | 13 |
| The task helped them develop an awareness of the myriad factors and resources that existed surrounding the issue | 25 |
| PTs valued the task of guiding them in recognizing and addressing issues of inequity | 16 |
| PTs as teachers | |
| PTs emphasized the benefit of connecting mathematics to the real life and students' daily lives in instruction | 10 |
| PTs recognized the accessibility of the task granted by multiple means of mathematical representations for students | 18 |
| PTs developed more confidence in their capability to implement culturally responsive teaching in their future classrooms | 4 |
| Total Number of PTs | 41 |

the proficiency with which students are capable of interacting with and interpreting them is crucial to the capacities to "understand and critique the existing social order" (Ladson-Billings, 1995) that lay at the heart of the culturally relevant pedagogies.

Analyses of responses also suggested that every participant took away a greater awareness of or concern for the social justice topics attached to the pothole damage task. About 61% (25/41) mentioned a key takeaway for them was an awareness of the myriad factors and resources that existed surrounding the issue. Responses ranged from those that "liked that the question(s) required thinking about the interconnectedness of things such as race, location and wealth" to those that "didn't know that you should report [potholes]" and the reasons citizens may be unable or disinterested in reporting. Participants found these takeaways important because these connections illustrated the effect of race and socioeconomic status on people's experiences and because they learned about a way they could personally report road maintenance issues.

39% of PTs (16 out of 41) appreciated that the task guided them towards identifying and taking action on issues of inequity. A PT noted issues with the fact that "potholes are only noted and repaired when reported, time to fix them varies based on location, population, demographics, etc." and several others mentioned this alongside the accessibility of reporting to lower socioeconomic status neighborhoods and the general effort to promote this avenue of reporting to all citizens. The pothole damage task seemed to "help students facilitate civic action and involvement in the community" and multiple participants noted the importance to "consider everyone. Even if things seem like a simple solution you need to think about if every single person can assess this." These responses demonstrate that most participants could identify several factors of a local issue and the social justice implications therein, with several finding their concern for equity and their agency in taking action supported.

Finally, mentions of the culturally responsive pothole damage task as a valuable instrument or reference for instruction occurred numerous times either as a key

takeaway or as the resulting importance of takeaways. The PTs who completed the task found that it provided an example of "how we can use relatable topics in our future classroom to encourage greater engagement." An important part of culturally responsive teaching is connecting students and content by tapping into "experiences, frames of reference, and performance styles" (Gay, 2018) of students. 10 of these responses mention the benefit of connecting mathematics to the real world and students' daily lives, while 18 responses mention the accessibility of the task granted by multiple means of mathematical representations and a topic relatable to students, along with the open-endedness of "experiencing the process and understanding how it can change thinking." Four of these participants mentioned more confidence in their ability to implement, but it is likely that many more are better prepared to implement culturally responsive pedagogy into their future classrooms based on the volume of qualities of the pedagogy that they identified as valuable to their teaching.

## Discussion and Conclusion

Our study indicates that the PTs' use of various approaches in response to the pothole damage task led to the noticing of equity through multiple lenses. The PTs used five related but diverse approaches, including an accessibility approach, an income-based approach, a dissemination approach, an analytics approach, and an alternative reporting approach. Each team of PTs utilized two to four approaches to create their models, and the most used approach is an income-based approach. This income-based approach helped PTs understand the large income disparity and inequities certain neighborhoods in the city experience. Additionally, many teams' proposals reflected an accessibility approach, which identified the inability to obtain reliable internet access as a reason potholes are not reported in certain neighborhoods. An alternative reporting approach, half of the teams' proposals used this approach to make it easier for citizens to report potholes, especially in low-income neighborhoods with limited internet accessibility. PTs of these teams combined several approaches involving income, accessibility, and alternative reporting approaches to address the inequity by recommending that the city can provide different reporting methods to ensure all residents have equal access to reporting services. The fourth approach, which was reflected in the PTs' action plans, was an analytics approach. PTs using this analytics approach addressed that city officials should research areas to find population densities and historic aspects of the road in order to get information on which communities should be helped first. For a social justice and equity perspective, the analytic approach recognizes the city's duty to help *all* its residents, regardless of race or income. Finally, the dissemination approach identified the need to fairly distribute information, such as using various forms of media to spread information about self-reporting and emphasize the importance of reporting potholes in the community.

The use of these approaches led the PTs to develop a better appreciation for mathematical literacy and awareness of social justice and equity issues. As other studies (e.g., Leonard & Evans, 2008, Gutstein, 2006; Turner & Strawhun, 2007) indicated, our study also confirms how STEM, especially mathematics, can support prospective teachers to see equity and social justice issues in their teaching with mathematical modeling tasks both as learners and as teachers. As learners, the contextually

rich mathematical modeling task, the pothole damage task, helped PTs appreciate the mathematics of everyday life, especially how mathematics can be a tool for exploring everyday life and making informed decisions on social issues. Their work also showed evidence of PTs engaging in particular modeling processes, such as understanding the context with critical eyes, making relevant assumptions, analyzing and working mathematically, and identifying a descriptive, sociocritical conclusion. As other teacher educators reported (e.g., Aguirre et al., 2019; Flavin & Hwang, 2024; Suh et al., 2023), when PTs engaged in modeling with a critical lens, these opportunities allow them to have critical discussions around important societal issues and recognize the role of mathematics in addressing these problems arise within and beyond their communities.

As teachers, the analysis of journal reflection revealed that the pothole damage task helped to deepen PTs' knowledge of culturally responsive teaching. PTs could identify several equity issues and the social justice implications in making connections between school mathematics and local communities of students (i.e., culturally responsive). We acknowledge that culturally responsive teaching goes beyond making sense of data that reveals societal situations and unfairness in the world. Our research study focuses on PTs' mathematical approaches and their understanding of culturally responsive teaching through a modeling task. Future studies could explore how PTs' learning of culturally responsive mathematical modeling tasks translates into their teaching in practice and the types of tasks they might design and enact for their students and communities.

As our intention as teacher educators was to support PTs to be aware of their role in social agency and the use of mathematics in the process (Aguirre et al., 2019; Barbosa, 2006). This study provides fruitful insights on how to support PTs to gain new perspectives toward mathematics teaching and understand culturally responsive mathematical modeling tasks. We propose that exploring how PTs utilize these experiences and perspectives post-course completion could be a valuable subject for future research. In addition, further research is needed to explore how PTs used different mathematical modeling tasks to promote equity and social justice and which tasks are most meaningful and informative for PTs and why. Our research sheds light on the diverse approaches PTs initiate to address societal issues when presented with opportunities to engage in a culturally responsive modeling task that is pertinent to their lives and communities.

## Appendix A. Pothole Damage Task and Relevant Data

Imagine that you will be placed in the position of data analyst for an activism group and have been asked to draft a proposal to this City A's Public Works Department for the better handling of local pothole data and maintenance.

Write a letter of proposal that includes answers to the following:

- How did you group and make sense of the pothole damage data sets (listed below)?
- What are the issues and implications with the current method for reporting potholes?
- What assumptions do you make, seeing the data at hand?
- What information do you wish you had? Why is this important for public knowledge?
- How can the city acquire this data? How should it be used?

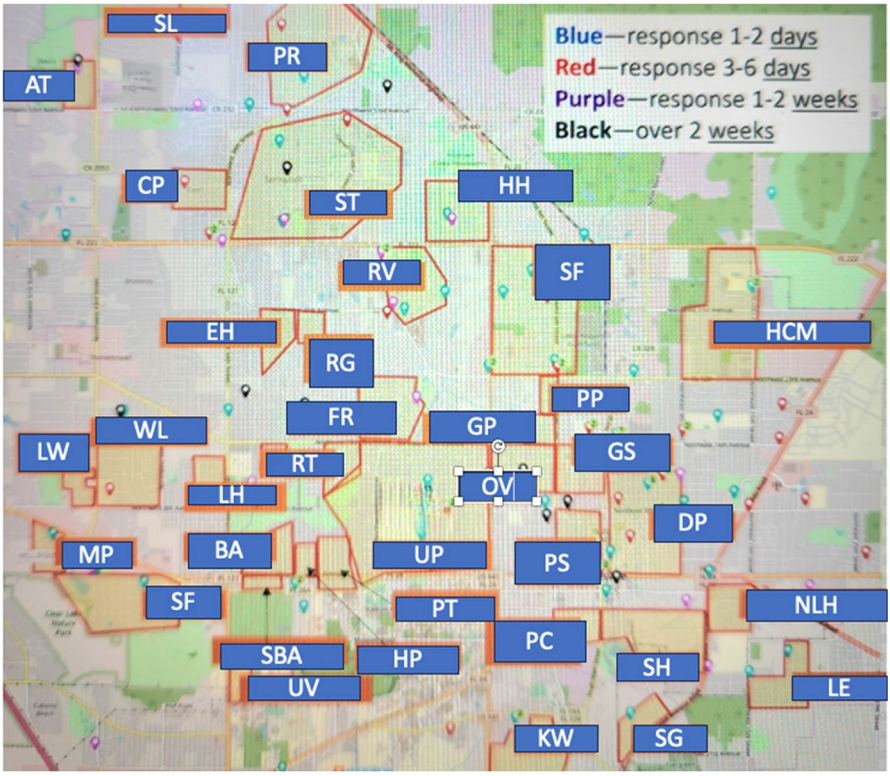
**Pothole Damage Data Sets**

(a) City A's current pothole reporting system

The asphalt repair patch crew responds and repairs potholes within the city limits. These concerns are usually generated by citizen inquiries. Routine scheduled maintenance is coordinated as needed.

- Approximate time that takes to fix potholes in general: usually two business days
- Who fixes potholes? Pavement management of selected streets is performed by in-house and outside contractors. This work is scheduled and maintained by asphalt section personnel.

(b) City A map, potholes reported by citizens, and wait time until being fixed




(c) City A income and race data, sample combined data

- Income and Race Table in City A

## 2021 References

| Initial of Neighborhood | Median Income | Asian | Black | Latinx | White | Mixed | Other |
|---|---|---|---|---|---|---|---|
| NLH | 26.6 k | 0 | 436 | 64 | 2 | 0 | 0 |
| SH | 32.1 k | 0 | 96 | 0 | 16 | 0 | 0 |
| LE | 26.9 k | 0 | 747 | 0 | 225 | 22 | 0 |
| HCM | 34.5 k | 12 | 1362 | 17 | 564 | 375 | 0 |
| P | 21.8 k | 26 | 390 | 21 | 226 | 2 | 0 |
| GP | 32.7 k | 11 | 126 | 10 | 121 | 7 | 2 |
| S | 30.3 k | 4 | 333 | 40 | 323 | 20 | 0 |
| KW | 25.1 k | 35 | 21 | 30 | 89 | 7 | 0 |
| OV | 22.9 k | 23 | 249 | 53 | 451 | 73 | 6 |
| GS | 22.9 k | 8 | 92 | 20 | 166 | 27 | 2 |
| PC | 39.3 k | 17 | 122 | 58 | 224 | 1 | 0 |
| SF | 44.7 k | 168 | 324 | 97 | 840 | 71 | 17 |
| MP | 35.6 k | 7 | 7 | 21 | 58 | 2 | 1 |
| ST | 49.4 k | 46 | 156 | 121 | 554 | 25 | 0 |
| CP | 64.7 k | 5 | 5 | 8 | 34 | 2 | 0 |
| FR | 68.8 k | 19 | 120 | 27 | 333 | 21 | 4 |
| WT | 39.7 k | 4 | 85 | 48 | 257 | 4 | 2 |
| RV | 39.1 k | 110 | 75 | 24 | 458 | 10 | 18 |
| HH | 49.9 k | 213 | 121 | 87 | 1051 | 36 | 70 |
| AT | 89.4 k | 15 | 3 | 9 | 80 | 4 | 0 |
| FA | 34.6 k | 28 | 220 | 89 | 1164 | 23 | 28 |
| LW | 80.5 k | 5 | 3 | 3 | 48 | 2 | 1 |
| SH | 80.5 k | 98 | 48 | 58 | 862 | 32 | 15 |
| DP | 49.1 k | 29 | 164 | 103 | 1298 | 56 | 0 |
| PS | 49.2 k | 2 | 130 | 16 | 598 | 13 | 0 |
| UP | 58.5 k | 49 | 61 | 714 | 3494 | 35 | 38 |
| SL | 70.6 k | 5 | 0 | 6 | 54 | 2 | 0 |
| WR | 61.3 k | 17 | 16 | 27 | 356 | 6 | 6 |
| LH | 61.3 k | 6 | 5 | 9 | 123 | 2 | 2 |
| BA | 41.5 k | 0 | 5 | 25 | 223 | 0 | 6 |
| HP | 41.5 k | 0 | 3 | 14 | 122 | 0 | 3 |
| SA | 41.5 k | 0 | 2 | 10 | 90 | 0 | 2 |
| PT | 41.5 k | 0 | 1 | 4 | 33 | 0 | 1 |
| UV | 41.5 k | 0 | 4 | 18 | 164 | 0 | 4 |
| RG | 95.5 k | 0 | 2 | 3 | 57 | 3 | 1 |
| EH | 95.5 k | 0 | 1 | 1 | 24 | 1 | 0 |
| SF | 50.8 k | 31 | 0 | 0 | 550 | 40 | 0 |
| RT | 92.2 k | 0 | 0 | 14 | 271 | 0 | 0 |
| RW | 92.2 k | 0 | 0 | 7 | 126 | 0 | 0 |

**City A Data Sample**

| | DP | ST | RV | HCM |
|---|---|---|---|---|
| # of potholes reported by residents | 18 | 8 | 6 | 2 |
| Wait time | | | | |
| 14 + Days | 0 | 0 | 0 | 0 |
| 7–14 Days | 1 | 0 | 3 | 0 |
| 3–6 Days | 8 | 2 | 1 | 0 |
| 1–2 Days | 6 | 5 | 2 | 2 |
| Populations | 1650 | 1517 | 133 | 2330 |
| Median Income | 49.1 K | 49.4 k | 39.1 k | 34.5 k |
| Race | | | | |
| Asian (%) | 1.7% | 11% | 0% | 0.5% |
| Black (%) | 9% | 21% | 0% | 58.4% |
| Latinx (%) | 13% | 8% | 5.2% | 0.7% |
| White (%) | 87% | 55% | 94.7% | 24.2% |
| Mixed (%) | 0% | 5% | 0% | 16.1% |
| Other (%) | 0% | 1% | 0% | 0% |

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We have gone through the appropriate process of obtaining approval for this research study. The authors also declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Authors and Affiliations

**William Reid Carlisle[1] · Hyunyi Jung[2,5] · Megan H. Wickstrom[3] · Kayla Sutcliffe[2] · Hee-jeong Kim[4]**

✉ Hyunyi Jung
hyunyi.jung@coe.ufl.edu; hyunyi.jung@tamu.edu

William Reid Carlisle
wrcgatorjr@gmail.com

Megan H. Wickstrom
megan.wickstrom@montana.edu

Kayla Sutcliffe
kaylajsutcliffe@ufl.edu

Hee-jeong Kim
heejeongkim@korea.ac.kr

[1] Kanapaha Middle School, Gainesville, FL, USA

[2] School of Teaching and Learning, University of Florida, Gainesville, FL, USA

[3] Department of Mathematical Sciences, Montana State University, Bozeman, MT, USA

[4] Department of Mathematics Education, Korea University, Seoul, South Korea

[5] Department of Teaching, Learning, and Culture, Texas A&M University, College Station, TX, USA