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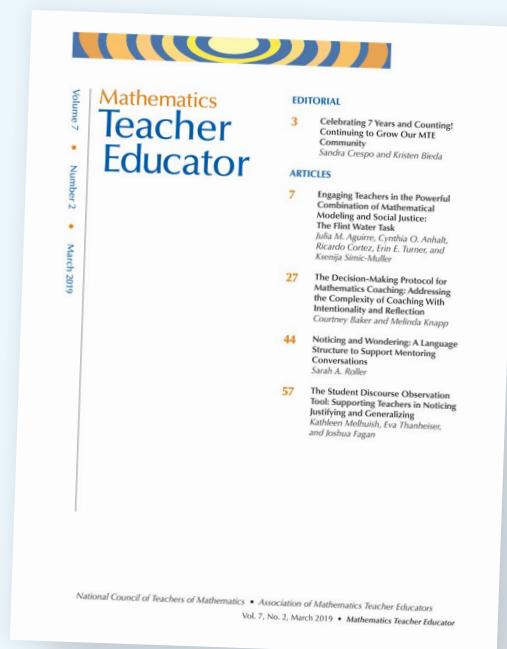
Mission Statement

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Cultivating K-8 Teachers' Critical Consciousness Through Social Justice Mathematical Modeling: The Teacher Pay Task

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Social justice mathematical modeling is powerful in helping teachers build awareness of social issues, critique existing systems, and engage in rich mathematical reasoning. In this article, we document a task in which 28 preservice teachers (PSTs) explored if teacher pay is fair and how to define “fair” mathematically. Through qualitative analysis of PSTs’ reflections, we studied the effectiveness of the task through the lens of critical consciousness. Twenty-six of the participants reported developing social and mathematical agency with respect to the task. Because the task related to PSTs’ lived experiences, it allowed them to examine their assumptions about teacher pay, empowered them to use mathematics to explore different perspectives, and helped them envision ways they could enact change.

Keywords: Mathematical Modeling; Mathematics; Social Justice; Teacher Education; Preservice Teachers

Mathematical modeling is the process of utilizing mathematics to understand authentic, real-world problems. Few K–8 preservice teachers (PSTs) have experienced modeling, and research is just beginning to emerge detailing modeling tasks and what PSTs glean from them. Modeling has the potential to be a powerful experience for learners in that it often lies at the crossroads of culturally responsive teaching, social justice, mathematical thinking and reasoning, and students’ identity and agency (Aguirre et al., 2019; Barbosa, 2006; Cirillo et al., 2016; Jung & Wickstrom, 2023). Designing mathematical modeling tasks that relate to current events can leverage both PSTs’ understanding of the event and empower them to use mathematics to explore claims (Aguirre et al., 2019).

In this article, we argue that mathematical modeling can also be used to leverage PSTs’ mathematical agency and identity. When PSTs experience a problem that is relevant and important to them, through modeling, they can develop tools to help them understand that they are capable of making sense of and solving important societal issues (Jung & Wickstrom, 2023). We describe a modeling task focused on using mathematical modeling as a tool to understand teacher pay and the ongoing societal question of whether teachers are fairly compensated. Similar to Aguirre et al. (2019), we found that this task was productive in engaging PSTs in mathematical modeling while making sense of social justice issues. Adding to this work, because this task connects to PSTs’ identities as teachers, we found that it allowed them to build critical consciousness—the ability to analyze systems that create inequities and develop a sense of agency (Friere, 1970; Kokka, 2020). By conceptualizing “fairness” in different ways, PSTs were able to see that there were different perspectives they could take on problems and that different mathematics could be used in relation to these perspectives. From written reflections, we explore how the task allowed for connections to their lived experiences and empowerment as mathematical thinkers, future teachers, and members of society. We also reflect on experiences incorporating modeling tasks into content courses for K–8 teachers to provide guidance and to encourage other mathematics teacher educators to engage in this powerful practice.

Perspectives on Modeling

Modeling is the process of using mathematics to solve real-world problems or problems that arise in one’s life (Blum & Ferri, 2009; Lesh et al., 2000; Niss, 1996). It often involves creativity and choice as students draw on their understanding of mathematics to frame and explore a problem using mathematics (Zbiek & Conner, 2006). Researchers conceptualize mathematical modeling through various perspectives (i.e., realistic, educational, models and modeling, socio-critical, and epistemology) (Abassian et al., 2020).

In our work with PSTs, we view modeling from the realistic (Pollak, 2007, 2016) and socio-critical (Barbosa, 2006) perspectives. In the realistic perspective, the emphasis is on the modeler making sense of real-life, messy scenarios through the modeling process, rather than specifically

learning mathematical content (Kaiser & Sriraman, 2006). The modeler encounters a real-world situation and then mathematizes the situation by interpreting it and examining “key aspects or variables to structure a real model” (Abassian et al., 2020, p. 55). Next, the modeler creates the model and draws on their findings to understand and make decisions about the situation. The purpose of modeling, from a realistic perspective, is for the learner to experience the modeling cycle and envision it as a tool to analyze and understand real-world situations (Abassian et al., 2020, p. 3).

Socio-critical modeling focuses on mathematical modeling as a tool to enact change and the agency of the learner as a decision-maker in society (Barbosa, 2006). This perspective builds on the work of Skovmose (1994) and is composed of two key objectives: “critiquing what is being learned is an important part of attaining knowledge, and second, mathematics can actively influence decision-making in society” (Abassian et al., 2020, p. 61). In the task documented in this article, we focus our primary attention on how PSTs experience the socio-critical aspects of the task.

We drew on these perspectives for two reasons. First, there is evidence that most teacher preparation programs, particularly elementary teacher preparation, do not include attention to the teaching and learning of mathematical modeling (Anhalt & Cortez, 2016; Doerr, 2007). The goal of modeling, from a realistic perspective, is to help the learner become more familiar with the modeling cycle. Incorporating modeling tasks into content courses for PSTs allows them to experience the modeling cycle, understand components of the process, and use the mathematics they are learning in creative ways.

Second, many elementary PSTs have not experienced mathematics in positive and purposeful ways and consequently have fragile mathematical identities and low self-efficacy (Bursal & Paznokas, 2006; Emenaker, 1996). They enter the college classroom with anxiety and shame (Ashcraft, 2002), often questioning their sense of belonging and ability to be successful. Both the realistic and socio-critical perspectives of modeling acknowledge and value prior knowledge and perspectives PSTs bring to the problem and connect mathematics to PSTs' lived identities, which fosters engagement (Aguirre et al., 2024; Jung & Wickstrom, 2023). Through modeling tasks, we wanted to develop PSTs' mathematical and social agency by supporting them in learning about modeling as a skill for life and empowering them to use mathematics to understand and explore issues that are important to them. For us, part of this work is to expand PSTs' notions of what it means to know and do mathematics, foster their creativity, and develop their sense of belonging in mathematical spaces.

PSTs as Modelers and Social Justice Modeling Tasks

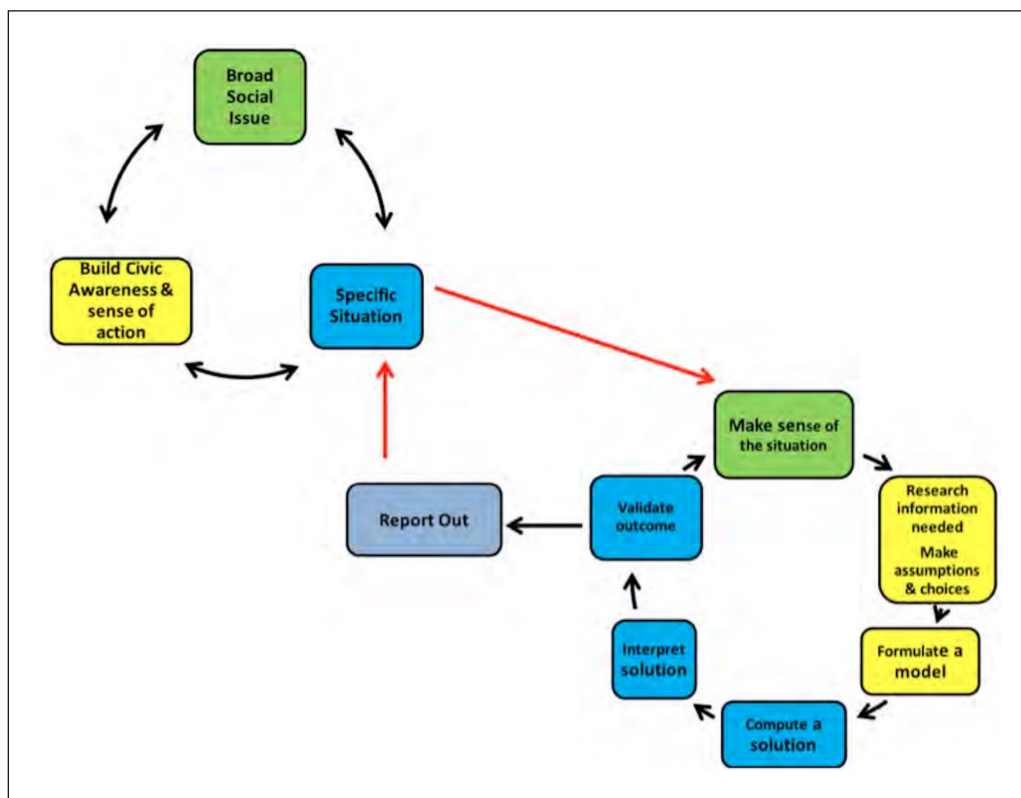
Social justice mathematical modeling (SJMM) tasks allow PSTs to engage in the modeling process while making sense of a real-world issue that is important to them. Jung and Magiera (2023) contextualized SJMM tasks through the following criteria: (a) the problem is situated in a context that addresses micro- and macro-level social justice issues, (b) the problem requires the development of a mathematical model, and (c) investigating the problem leads to results that can be shared with a broader audience that cares about the issue. SJMM is of particular importance because of the ways it can foster connections between PSTs' lived experiences and mathematics (Aguirre et al., 2019; Anhalt et al., 2018; Barbosa, 2006; Cirillo et al., 2016; Jung & Wickstrom, 2023).

Few studies explore teachers' experiences of learning about mathematical modeling tasks with an emphasis on social justice (e.g., Aguirre et al., 2019; Felton-Koestler, 2020; Jung & Magiera, 2023; Seegmiller, 2020), but their findings have been powerful. Most notably, Aguirre et al. (2019) engaged teachers in an SJMM task where they investigated the drinking water needs of the people of Flint, Michigan, following an environmental crisis in which aging plumbing infrastructure rendered tap water toxic. They considered how teachers engaged in the modeling cycle and developed a conceptual framework that illustrated how the modeling cycle was related to teachers' understanding of a social justice issue in an SJMM task (see Figure 1).

In the figure, they illustrate that when teachers are engaged in the modeling cycle, they are learning about a specific situation and how to use mathematics to investigate claims. Once they create a model, they are able to revisit the situation, with their findings in mind, to build greater awareness of the issue. Building from this work, Jung and Wickstrom (2023) engaged teachers in an SJMM task where they had to determine a fair way to distribute school funding. They found that when the SJMM task connected directly to teachers' lived experiences, teachers' understanding of social justice was intertwined across the modeling cycle. For example, when teachers had to make sense of the situation and define “fair funding,” they researched, brainstormed, and critiqued existing sources. From the start, they wanted to define fair in an equitable way. Beyond learning about mathematical modeling and social justice issues, engaging in tasks like these allows teachers to critique existing systems (Jung & Wickstrom, 2023) and also ponder related modeling questions that could be helpful in understanding the situation (Aguirre et al., 2019).

Figure 1

A Conceptual Interaction Between Mathematical Modeling and Issues of Social Justice (Aguirre et al., 2019)



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SJMM tasks are important because they allow for PSTs to experience tasks from the learner's perspective, both with respect to modeling and social justice. It is important for PSTs to engage in the process of modeling as learners before they can consider how to design tasks and implement these practices in their classrooms (Anhalt & Cortez, 2016; Cai et al., 2014; Niss et al., 2007). With respect to mathematical modeling, SJMM allows teachers to conceptualize what the modeling cycle is, conceptualize related competencies, and reflect on how the task was enacted (Anhalt & Cortez, 2016; Gould, 2013; Wickstrom & Jung, in press; Zbiek, 2016). From a social justice perspective, SJMM tasks are crucial because they allow PSTs to see that social justice issues are not ancillary or non-existent in the mathematics classroom (Rodriquez, 2005; Simic-Muller et al., 2015). PSTs experience first-hand how they can draw on their mathematical and personal knowledge as tools to make sense of a societal issue (Bartell, 2013; Aguirre et al., 2019). Tasks like these also increase PSTs' awareness of social justice issues and draw their attention to related contexts that might be relevant to their students and local community. We cannot expect that PSTs will have the courage to try SJMM tasks in their

own classroom if they have not experienced these tasks as learners.

Connecting Critical Consciousness and Social Justice Mathematical Modeling

Freire (1970) stated that critical consciousness means "learning to perceive social, political, and economic contradictions and to take action against the oppressive elements of reality" (p. 35). In this definition, Freire and subsequent scholars (e.g., Gutstein, 2006; Ladson-Billings, 1995; Jemal, 2017) have identified two components: critical reflection and critical action. Critical reflection is the ability to reflect on and analyze existing societal systems. Gutstein (2006) discussed this as being able to "read the world" through mathematics and use mathematics as a lens to think critically about issues in society. Jemal (2017) built from this definition and discusses that critical reflection also encompasses critical awareness. Citing Houser and Overton (2001), she stated, "This critical awareness incorporates perspectives of relationships between self and society and requires metacognitive experiences in that one

must think about their thinking, be aware of the existence of consciousness, and be mindful of its ever-evolving process." (p. 606). Critical reflection means not only reflecting on a particular societal issue, but also reflecting on our own beliefs and assumptions about the situation.

Critical action can be defined as "the overt engagement in individual or collective action taken to produce socio-political change of the unjust aspects of society (e.g., institutional policies and practices) that cause unhealthy conditions" (Jemal, 2017, p. 408). Action can take on many different forms. It can be on the individual level, including sharing advice and support (Hatcher et al., 2010), or it might be taking more formal actions like organizing community groups to enact change. Jemal (2017) stated that there is a step between reflection and action, in that people do not normally act unthinkingly. We ought to have the opportunity to analyze social conditions to understand them and think about how to act to change them (Jemal, 2017; Freire, 1970).

In Figure 2, we capture these three dispositions (reflection, analysis, and action) in relation to SJMM tasks. As the modeler encounters the situation, she comes to understand a societal issue and her assumptions and beliefs about it. As she creates a model to address the situation, she is able to analyze and critique the problem and understand how different approaches illuminate

different perspectives on the problem. Finally, once the model is created, it gives the modeler the opportunity to use mathematics as a tool to encourage discussion and enact change.

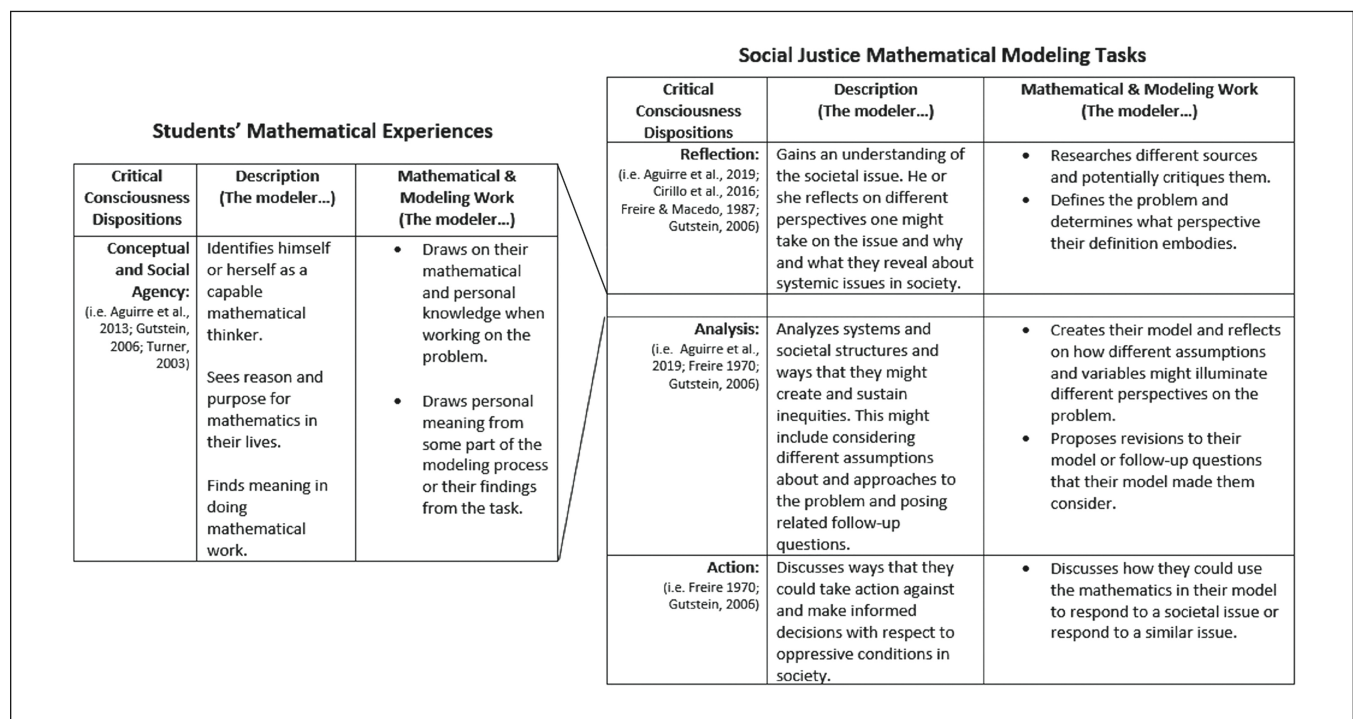
When engaging in SJMM tasks and exploring and responding to societal issues, there is the opportunity to empower the learner as both a mathematical thinker and a member of society. We show this on the left side of Figure 2. Agency is when students "identify themselves as powerful mathematical thinkers who construct rigorous mathematical understandings, and who participate in mathematics in personally and socially meaningful ways" (Turner, 2003, p. iv). By engaging in an SJMM task, learners have the opportunity to develop different types of agency. With respect to the SJMM issue, they might develop societal agency with respect to enacting change for themselves and others. The learner might also develop conceptual agency (Aguirre et al., 2024) with respect to the discipline by developing new mathematical ideas or discovering something they love about doing mathematics through modeling.

The Modeling Task

We developed the Teacher Pay task as part of an NSF-funded project that aimed to design, implement, and

Figure 2

Connections Between Critical Consciousness Dispositions and the Modeling Cycle



refine mathematical modeling modules in elementary teacher education programs. When designing the task, we looked for societal issues that PSTs would be passionate about and about which they would have insider knowledge to share. As future teachers, we thought that a question centered on teacher pay would be highly relevant. Across the three authors, we have enacted the Teacher Pay task in both mathematical content courses and designated mathematical modeling courses. In mathematical modeling courses, we had time to leave the prompt open for PSTs to explore and have the autonomy to determine what resources to draw on and how they would use mathematics to make sense of claims about teacher pay. In content courses, we wanted PSTs to engage in modeling, but we typically had less time to enact the task. For these enactments, we often provided targeted materials related to the mathematical content addressed in the course or used different pedagogical strategies to manage the constraints of limited time. For example, the second author, Christian Lopez-Mercado, was teaching statistics to PSTs and chose to give them a data set of early- and mid-career teacher salaries as a starting point for them to explore the Teacher Pay task. The third author, Hyunyi Jung, implemented the task across several sections of an elementary content course in a 75-min session without time for homework, ensuring all course contents received balanced attention. To accommodate this timeframe, she chose simultaneous in-class discussion (e.g., use of Jamboard) over individual written reflections for homework. From our perspective, diverse approaches to teaching the task are valuable and meaningful to PSTs and teacher educators. In the [Appendix](#), we provide an annotated lesson plan for the entire modeling task and examples of PST models.

Next, we describe how this task unfolded in our classrooms with respect to the modeling cycle. In our previous work (Jung & Wickstrom, 2023), we drew on Bliss and colleagues' (2014) components of the modeling cycle and expanded them to include ways in which these components could be connected to SJMM. The components of the modeling cycle include the following:

- a. Defining the problem: When learners define the problem, they will define both the mathematical problem and the social justice problem;
- b. Making assumptions: Learners will make assumptions based on their societal knowledge and understanding of mathematical data presented in the problem;
- c. Defining variables: Learners will define variables based on the assumptions connected to societal and mathematical spaces;
- d. Research and brainstorming: When learners research and brainstorm ideas, they will critique existing ideas in relation to their understanding and values;
- e. Building the mathematical model: The mathematical models that learners develop will be used to solve societal issues;
- f. Getting a solution: The solution integrates both mathematical and social justice concepts.

We began by introducing PSTs to the problem and giving them time to think and discuss. Next, we gave them time to work in groups to research and brainstorm the situation, discuss assumptions, and define variables as they consider which mathematics seems appropriate and why. Once they had an approach in mind, they began to propose and construct the first drafts of their model (Jansen, 2020). Next, we structured class time for PSTs to present their ideas and receive feedback, which they drew on to revise and design their final draft.

Defining the Problem

To prepare for the task, we provided articles and videos highlighting different perspectives on teacher pay. We included an article about why teachers quit the profession, a video highlighting a teacher's journey balancing multiple jobs, and an article asserting that many members of society believe teacher pay is fair given the hours worked (see [Appendix](#)).

After reflecting on the sources, we posed the following question for PSTs to explore:

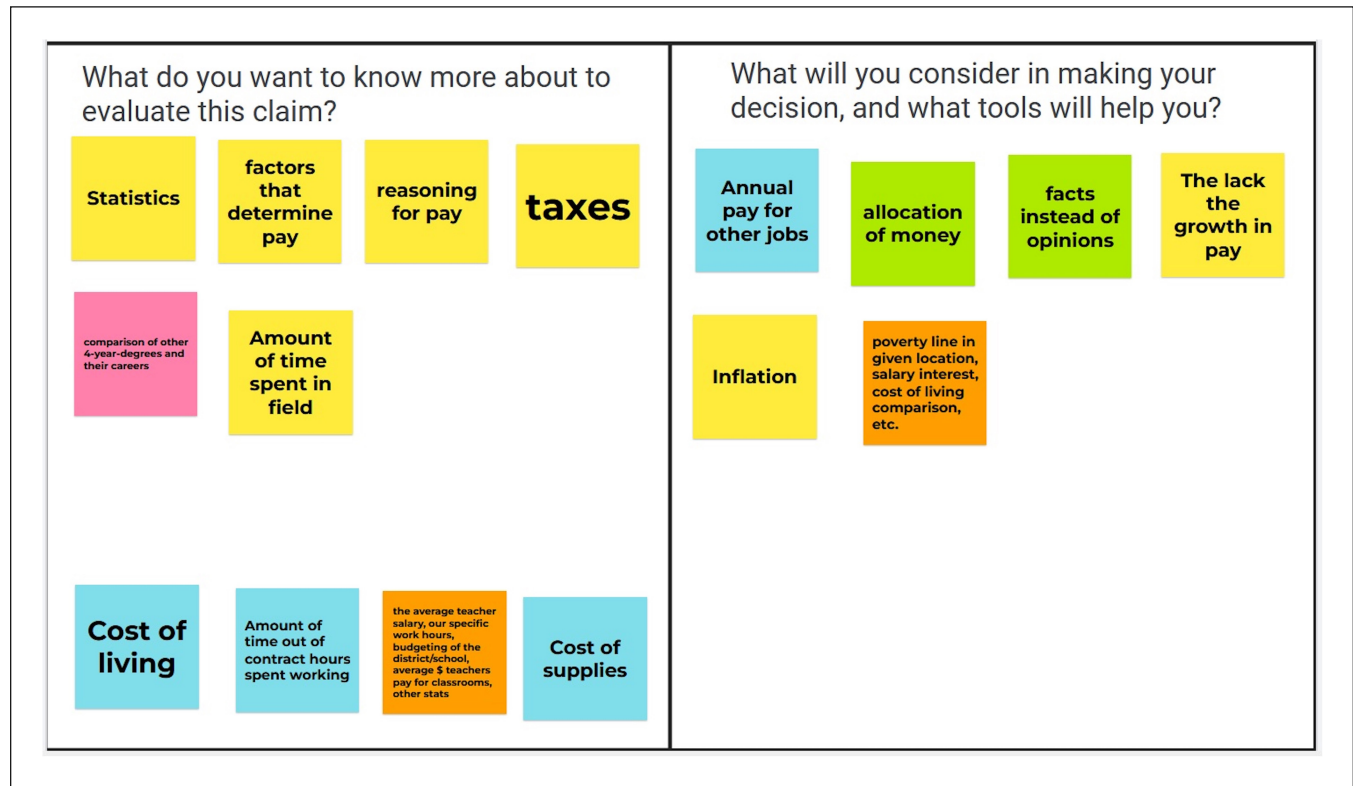
Recently teachers have been striking across the country advocating for higher wages while others argue that teachers are paid a fair salary. Imagine you are working for your state government or a local teachers' union in charge of adjusting teacher pay. "How much do you think new teachers should be paid? Is their pay fair?"

We asked them the following questions related to this prompt:

- What do you want to know more about to evaluate this claim?
- What tools will you consider in making your decision?
- What tools might help you?

Before diving into mathematical work, we took time to reflect on teacher pay. PSTs shared that they believed teachers leave the field because of lack of respect, stress, and limited support structures. Some PSTs shared assumptions they had heard that teachers' pay is less because it accounts for 9 months of work instead of 12. Other PSTs reflected on the prompt in relation to their lives. Many discussed that they knew their pay would be

Figure 3

PSTs' Initial Thoughts About the Task

less than their peers, but they had not explored if their salary would be enough to support future life goals, like owning a home or paying off student debt. This discussion revealed that PSTs had assumptions and beliefs about teacher pay going into the task.

We also provided opportunities for PSTs to answer the three questions we provided collectively as a group and think about which of these questions they might be able to use mathematics to answer. Figure 3 shows PSTs' responses and includes evaluating factors that determine

pay, cost of living, cost of supplies, hours worked, and comparison to other jobs.

Developing a Model

As PSTs began to develop their models, they had to wrestle with how to conceptualize "fair" and "equitable" in mathematical ways. Across multiple rounds of enactments, we have documented that PSTs typically draw on one or more of the following approaches to construct their models: inflation, comparison, and cost of living. Table 1 shows that each

Table 1

PSTs' Approaches to the Modeling Task

	Historical/inflation approach	Comparison approach	Cost of living approach
Description of Approach	PSTs analyze the cost of common expenses across time (house, gallon of gas, loaf of bread, etc.) and see what claims they can make about teacher pay in relation to these items.	PSTs analyze data summarizing starting salaries for different professions following a 4-year degree. PSTs analyze starting teacher salary and mid-career salary across 50 states.	PSTs examine living wage to analyze if where they want to teach is livable given a certain salary.
Definition of Fair Salary	Fair means salary keeps up with the cost of living/inflation.	Fair means that similar skill sets are compensated the same.	Fair means that someone can live comfortably on their salary.

mathematical approach is often guided by how the PST conceptualizes fairness.

Next, we share an example of a group's approach. One group determined that fair means teachers could live comfortably, and that comfortably meant that one-third of a salary for any working person should be allocated for spending and savings. Next, they discussed the assumptions they were making, defined variables, and researched and brainstormed. They decided they would consider variables of student loans, renting vs. buying, and living with roommates. They looked for resources to understand what the reality is for most teachers and how taxes are used to fund teacher pay. Next, they began to construct their mathematical model. In this case, PSTs determined a third of the salary should be allocated to saving and spending. They created a model to determine which cases allowed this to happen. After they had a rough draft of the model, they were given the opportunity to evaluate colleagues' approaches and perspectives on the problem to determine if and how they wanted to make changes to their model and provide suggestions they could give classmates to improve their approach. Figure 4 is an artifact of their work. They found that of the eight scenarios they investigated, only two were deemed "fair" based on their initial model. In describing their findings, they stated,

According to our model, within eight realistic scenarios, only two times was teacher pay considered FAIR. These times were both in scenarios where the teacher is RENTING and HAS 3 ROOMATES. Now, you be the judge, but I would consider those to be relatively harsh sacrifices to make.

Reporting Solutions and Reflecting on the Problem

We ended the modeling task by having each group present their findings—allowing PSTs to see that there are different ways to approach the problem and, in this situation,

definitions of fairness dictate this. They are also given the opportunity to reflect on their approach in relation to other approaches and what they have learned about teacher pay overall. In describing their approach, the Cost of Living group stated that the task caused them to question if teacher pay was ever fair and if it is reasonable to compare teachers' pay to that of employees of private companies. Reflecting on their approach, they stated,

We took a unique approach in that our model was not based on the past or other professions. We believed that as a government funded and nationwide occupation, you cannot compare teacher salaries to other salaries that are part of a capitalistic and individualized system. We also believed that if teaching was never historically "fair", then looking at the past and modeling predictive trends was also not a good way to properly determine a fair salary.

The **Appendix** provides a description of two other approaches in detail.

Studying the Impact of the Teacher Pay Task

Data Collection

This task has been taught in six different classes (four elementary content and two modeling courses) by four different instructors, including the three authors of this article. In this study, we sought to study the effectiveness of the task through the lens of PSTs' critical consciousness (Friere, 1970; Kokka, 2020). In particular, we wanted to answer the following question:

In what ways, if any, did PSTs report instances of engaging in critical consciousness (reflect on their

Figure 4

PSTs' Cost of Living Analysis

Scenario	Renting, No Roomates, No SL	Renting, No Roomates, With SL	Renting, 3 Roomates, No SL	Renting, 3 Roomates, SL
Salary	\$36,626.00	\$36,626.00	\$36,626.00	\$36,626.00
Savings/Spending \$	\$6,064.20	\$3,452.76	\$15,033.00	\$12,421.56
Savings/Spending \$ as a Percent of Salary	16.56%	9.43%	41.04%	33.91%
FAIR?	NO	NO	YES	YES

Buying, No Roomates, No SL	Buying, No Roomates, SL	Buying, 3 Roomates, No SL	Buying, 3 Roomates, SL
\$36,626.00	\$36,626.00	\$36,626.00	\$36,626.00
-\$71,835.00	-\$74,446.00	-\$1,810.00	-\$4,421.00
-196.13%	-203.26%	-4.94%	-12.07%
NO	NO	NO	NO

understanding of the situation, exhibit mathematical agency in relation to the task, analyze the situation, and discuss ways that they could take action) following the Teacher Pay task?

To answer this question, we drew on PSTs' individual written reflections as our primary data source to identify instances where they expressed critical consciousness. We analyzed reflections written by 11 PSTs enrolled in a designated modeling course for elementary education majors and 17 PSTs enrolled in a capstone content course for elementary education majors; both groups had little to no experience modeling before this task. Both groups were drawn from institutions in the Rocky Mountain West region of the United States and had successfully passed all mathematics courses for their major. PSTs were typically sophomores or juniors.

We chose to analyze the journals because we found that PSTs' mathematical work did not always capture the whole story of PSTs' experiences with the problem. In their journals, they often reflected on their perspectives on the problem and how their thinking grew and changed. Their journals provided a narrative of the choices they made while completing the task and why and gave us insight into what they learned about themselves and societal issues through the task. In two enactments of the task, PSTs were given reflection questions to consider after creating their models. They included the following:

- How useful have you found this task to you personally? Describe specific parts that you found useful and why.
- How useful have you found this task to you as a teacher? Describe specific parts of the task that you found useful and why.
- Describe any pivotal moments (both negative and positive) you had while working on the task. What experiences prompted these feelings?
- What have you learned so far from working through this task (about mathematical modeling, your mathematical self, etc.)?

PSTs typically wrote a paragraph response for each question. We drew these questions from research on engagement, affect, and motivation (Middleton et al., 2017). Specifically, we were curious about the utility of the task for the PSTs and why, as well as the emotions they encountered during the task.

Data Analysis

Following the qualitative methods of Miles et al. (2014), we first organized the data by question so we could

examine all PSTs' responses with respect to each reflection question. Next, the first two authors read through each PST's response to each question and took notes on where they saw instances of reflection, agency, analysis, and action. When we looked for instances of reflection, we noted how PSTs expressed understanding of the situation and reflected on their own and others' assumptions and beliefs about the situation (Gutstein, 2006; Houser & Overton, 2001; Jemal, 2017). When looking for instances of analysis, we looked for ways that PSTs continued to understand and critique societal structures, including posing additional questions related to their model or other potential models that would help them seek additional knowledge about teacher pay (Aguirre et al., 2019; Friere, 1970; Gutstein, 2006). For action, we looked for ways that PSTs discussed taking action following the task and ways they planned to enact change personally and systemically. When considering instances of agency, we looked for ways in which PSTs discussed their agency with respect to the task and their agency within mathematical spaces. These ways might include feeling empowered to use mathematics as a tool in their lives, discussing growing confidence in tackling mathematical problems, or expressing joy and accomplishment in creating a visual to share with classmates. In a sense, we were looking for how PSTs felt empowered by or connected with mathematics on a personal level.

In the second step of the analysis, we drew on our memos to establish descriptive codes that pertained to each of the four categories. In the first round of coding, the first two authors independently coded and met to discuss discrepancies they found when coding. This allowed for the codes to be reviewed and collapsed or separated into additional codes and for code descriptions to be clarified and refined. This process happened twice. In the second round of coding, the authors had 84% agreement. The first author met with the third author to go over the codes and examples. Subsequently, the third author scrutinized all the codes and data as an informed outsider, enabling our analysis to leverage three perspectives and facilitating the establishment of consensus on the codes (c.f., Lincoln & Guba, 1985). Table 2 illustrates the codes we identified in relation to each of the critical consciousness dispositions in the modeling task, and Table 3 illustrates the codes related to mathematical agency. Coding in this way allowed us to identify how many PSTs demonstrated critical reflection, analysis, and action during the SJMM task and how they reflected on the task overall with respect to their sense of agency.

Positionality Statement

Hyunyi Jung and Megan Wickstrom are modeling researchers with multiple years of experience working

Table 2

Qualitative Codes for Each Critical Consciousness Disposition Related to the SJMM Task

Dispositions	Code	Description
Reflection: The PST gains an understanding of the societal issue. He or she reflects on different perspectives one might take on the issue and why and what they reveal about systemic issues in society.	Understand Situation - Cost of Living	PST reflects that the task helped them to better understand teacher pay in relation to cost of living.
	Understand Situation - Comparison Between Occupations	PST reflects that the task helped them to better understand teacher pay with regard to comparisons between different occupations or comparisons of teacher pay across multiple states.
	Understand Situation - Pay Across Time/Generational Differences	PST reflects that the task helped them to better understand pay across time with respect to different generations and their families.
	Reflection on Choice to Become a Teacher	PST describes that the task made them reflect on their choice to become a teacher and their reasons for doing so.
	Understand Societal Perspectives	PST reflects that they have a better understanding of different societal perspectives on teachers' pay.
	Understand Classmate's Perspectives	PST discusses that through their classmates they were able to see different perspectives on the problem and understand why different approaches could be warranted.
	Challenged Beliefs	The findings challenged what PSTs assumed about the situation. PST reflected on how they understood the situation differently now.
	Feelings/Emotions about the Situation	PST expressed that after reflecting on the situation they experienced emotions related to what they found.
Analysis: The PST analyzes systems and societal structures and ways that they might create and sustain inequities. This might include considering different assumptions about and approaches to the problem and posing related follow-up questions.	Variables in the Situation	PST discusses that they want to analyze how different life circumstances (variables) affect the outcome of their model (e.g. children, illness, long-term expenses).
	Extension of Task	PST poses additional questions related to the model they created. (e.g., Do better paid teachers better prepare students?)
	Improve the Model	PST discusses that with additional research they could continue to improve their findings to better support their claims.
	Explore Models	PST ponders what other models exist and have been used to evaluate the situation in relation to what they have created.
Action: The PST discusses ways they could take action against and make informed decisions with respect to oppressive conditions in society.	Advocacy/Conversations	PST discusses how they can use what they found to advocate for themselves and engage in conversations to promote change.
	Inform future decision making - budget and spending.	PST discusses that this task influences how they will think about making monetary decisions in the future.
	Inform future decision making - where to teach.	PST discusses that this task helped them to feel informed to evaluate which city or state would be best to teach in.
	Inform future decision making - preparation and schooling.	PST discusses educational steps they can take as a teacher to advocate for themselves and be paid more (e.g. graduate school).

alongside K-12 students and teachers. We both value equity and access in mathematics teaching, ensuring that every student and PST has opportunities to experience high-quality, challenging mathematics curricula and instruction (AMTE, 2017; NCTM, 2014). We approached this modeling task through design-based theories (Cobb et al., 2003), positioning ourselves as learners, teachers, and researchers. Christian Lopez-Mercado is a Ph.D. candidate and volunteered to implement the task for us.

After he experienced the task, he thought it was impactful and we invited him to collaborate with us. All three authors participated in the enactment of the tasks and data collection and analysis while observing and learning from each other's teaching. Across the implementation of tasks like these, our biggest takeaway is that PSTs are consistently underestimated in what they can do and create mathematically. They are capable of sharing innovative, high-quality solutions when provided with

Table 3

Qualitative Codes for PSTs' Mathematical Agency

Dispositions	Code	Description
Mathematical Agency: The PST identifies himself/herself as a mathematical thinker capable of developing meaningful mathematical understanding and constructing powerful representations in relation to their lived experiences. They see reason and purpose for mathematics in their lives and/or find meaning in doing mathematical work.	Math can provide evidence to back a claim.	PST describes that they can use their mathematical findings to back the claim that teacher pay is not fair.
	Math is a tool to understand a situation in our world.	PST describes that mathematics can help to represent and understand a situation and make decisions.
	Math can be engaging and enjoyable.	PST discusses that math can be interesting or enjoyable.
	Mathematical modeling tasks can deepen mathematical understanding.	PST describes that engaging in a real-world problem can grow their mathematical thinking.
	Relevancy	PST describes that the task was particularly relevant given PST's identity as a teacher.
	Confidence	PST discusses that this task built their confidence to address other problems.

rich learning opportunities and consistently bring unique and innovative approaches to the modeling process. Our goal, through this work, is to elevate PSTs as knowers and doers of mathematics, foster inclusion and belonging in mathematical spaces, and convince others that this work is possible and valuable.

Evidence of Impact: Developing PSTs' Critical Consciousness

In this section, we share our findings related to reflection, agency, analysis, and action and how these constructs of critical consciousness were expressed in PSTs' journals.

Reflection

All of the PSTs expressed reflection when considering the Teacher Pay task, with respect to the work they had done on the task, different approaches to the problem, or self-awareness (see Table 4). All PSTs reflected on their awareness of teacher pay with respect to the findings from their model, drawing on the different perspectives highlighted in the task. Twenty-four PSTs reflected on the task with respect to cost of living. One PST stated, "I have learned (keeping my own biases in mind) that first-year teacher salaries are not fair. We stated that fair means an appropriate salary that an individual can survive off of and still have a surplus of money for life's wants and needs." Twenty PSTs reflected on teacher pay broadly, eight reflected on comparing teacher pay to other professions, and five reflected on differences in pay across generations. In reflecting on pay across generations, one PST stated,

Personally, this task has made me realize how much inflation has affected the way people live, and not just teachers. Seeing how the price of everyday items like a gallon of gas and a housing payment have increased so dramatically over the past 90 years blew me away. I always knew prices today are not what they were back then, but when we put real numbers to these items, I couldn't believe that people today can still afford anything, especially teachers.

PSTs also reflected on different perspectives about teacher pay. Seven PSTs discussed classmates' approaches to the task and that different approaches to the task could illuminate different perspectives one might take on the problem. Five PSTs reflected on understanding different societal perspectives on the problem, like why the public might believe teachers are paid a fair salary or why teachers might move to a different state for better pay. In describing perspectives on the problem, specifically teachers' perspectives, one PST stated, "With this new view on teacher pay, I now see why so many teachers go on strike or advocate for their paychecks."

PSTs also engaged in self-reflection or their awareness of the problem, following the Teacher Pay task. Eighteen PSTs openly talked about emotions or feelings they had when interpreting the results of the model using words like sad, angry, or disheartened. Twelve PSTs shared that what they found challenged their beliefs about the situation. For example, one group assumed that teacher pay would be reflective of the cost of living in a particular city and that moving to a more prosperous place would allow for better pay. They stated, "We assumed teacher pay would be better or worse depending on the city's cost of living or how affordable the city is. However, the discrepancies were not

Table 4

Counts for Qualitative Codes Across Critical Consciousness Dispositions

Disposition		Codes	Count	Count by disposition (n = 28)
Reflection	Reflection on findings from the model	Reflection on cost of living	24	28
		Reflection on teacher pay broadly	20	
		Reflection on the situation by comparing teachers with other occupations	8	
		Reflection on generational differences in pay across time	5	
	Perspectives on the problem	Understand classmates' perspectives	7	
		Understand societal perspectives	5	
	Self Awareness	Feelings/emotions about the situation	18	
		Challenged beliefs	12	
		Reflection on becoming a teacher	9	
		Variables in the situation	6	
Analysis		Extension of model	5	12
		Explore models	2	
		Improve the model	1	
Action	Societal Personal	Advocacy/conversations	5	20
		Inform where to teach in the future	11	
		Inform future budget and spending decisions	6	
		Inform future schooling decisions	2	

as large as we originally thought." Other PSTs used words like shocked or surprised to discuss how what they found challenged what they initially believed about the situation. Many believed that teachers' pay would be less than other professions, but they did not realize the extent. Lastly, nine PSTs reflected on their decision to become a teacher, and the task caused them to pause and reflect on whether this was the right career decision. One PST stated,

I really reflected and realized that I had initially gone into this career choice without money in mind and that all I really want to do is help children flourish. I realized that my motives have not changed and that it is okay if I struggle at times if I am doing what I love.

Analysis

After creating their models, a smaller number (12 out of 28 PSTs) engaged in analysis and sought knowledge about the systems and structures that create and sustain inequities. As shown in the table, the knowledge that they sought was regarding the models they created. Six PSTs wondered about how accounting for different variables with respect to teacher pay might affect their findings. Most PSTs created models that captured first-year teacher pay, assuming that teachers did not have significant others

or dependents and limited medical expenses. Many discussed that their models were capturing a best-case scenario and not necessarily the realities of life. Reflecting on the variables they considered, one PST stated, "I would have personally wanted to compare these models to other cities/counties or look at what it would look like if there were children or significant others in the picture."

Another PST, reflecting on the realities of daily life, stated,

What if a random life expense happens to pop up? Or your car breaks down? Or there is some crazy natural disaster that ruins your home? With the expenses that teachers have and the low salary there is not much of a safety net for random life-altering events.

Findings from the model often caused PSTs to consider extension questions related to their model (five PSTs). For example, one PST wondered "if there is any correlation between student success and how well teachers are paid." Two PSTs discussed fairness models in general and wondered how they might be able to use what they created to address other situations. One stated, "I think this model was interesting because it dealt with the idea of 'fairness'; it would be interesting to see what other modeling tasks deal with fairness and how you could use that in the classroom." Lastly, one PST discussed improvements

to the model, stating, "Models can always be enhanced and changed to tell us new information."

Critical Action

Our analysis of PSTs' reflections on critical action resulted in two distinct types of action: (1) societal critical action and (2) personal critical action. In the former categorization, PSTs discussed ways they could act *against* oppressive conditions in society. In the latter categorization, PSTs discussed ways they could make decisions or navigate *within* the existing system.

Societal Critical Action

Out of the 20 PSTs who expressed critical action, five of them explicitly stated ways they could start conversations promoting change to advocate *against* existing conditions. One example of this is the excerpt "As big advocates for livable wages in general and as future teachers, we have found this task to be useful for engaging in meaningful conversation that may lead to increased teacher pay." This theme is also well captured in another PST's reflection:

I absolutely found this task personally useful. As a future teacher, I have learned that I must advocate for myself to ensure that I am being paid fairly. This means when I am initially hired and when I have been working for a while, I will request a pay increase and I will have math to back me up.

Many PSTs discussed that they had the realization that they could draw on mathematics to help them understand and respond to societal issues.

Personal Critical Action

Although some PSTs did not explicitly state ways they could act *against* existing conditions, others expressed ways they now had tools that they could use to navigate and act *within* existing conditions. For instance, six PSTs stated that this modeling task informed future budget and spending decisions to deal with the "unfairness" (by their standards) of teacher pay. One PST stated, ". . . this task was useful for me as a future teacher because it made me realize certain steps I should be taking to make the most out of my money." Some PSTs (11 out of 20) similarly expressed themselves but also focused on various places or states they can teach to make the most out of their income. The following reflection captures this:

This task is useful to us because we are planning to become teachers ourselves. It is helpful to get a better understanding of how our pay compares to the cost of living in the different states to know where we will be able to afford to live or where we might not be able to afford to live.

Two PSTs considered teacher pay in relation to their academic degrees (teacher with bachelor's or master's degree) across states and took a slightly different approach than all the other PSTs expressing critical action. These PSTs felt that the modeling task informed future schooling decisions and stated that "we have learned that. . . you are going to be better off working for and getting a higher degree if you want to live comfortably."

Mathematical Agency

Reflecting on the modeling process overall, the vast majority (26 out of 28 PSTs) reported either social agency with respect to the societal issue of teacher pay or conceptual agency with respect to knowing and doing mathematical work (see Table 5). In relation to the Teacher Pay task, they considered this modeling task highly relevant, which helped them view mathematics as a powerful tool to understand real situations in the world and support their claims. They also expressed a higher level of confidence and engagement when working with mathematics and showed genuine enjoyment that helped deepen their mathematical understanding.

Out of these 26 PSTs, 12 of them stated that mathematics is a tool to understand real situations in the world. One PST even pointed out that ". . . not all models are perfect" and that "models can always be enhanced and changed to tell us new information," which is a key feature of mathematical modeling. Thus, not only did they state that mathematics is a tool to understand the world, but they also went beyond explaining how these models can change depending on the situation at hand. Moreover, nine of them stated that this modeling task provided them with evidence to support their claims (i.e., that teacher pay is unfair), which is a glimpse into how much

Table 5

Counts for Qualitative Codes for Mathematical Agency

Disposition	Codes	Count	Count by disposition (n = 28)
Mathematical Agency	Relevancy of the Task	22	26
	Math is a tool to understand a situation in the world	12	
	Math can be engaging and enjoyable	12	
	Deepen mathematical understanding	11	
	Evidence to back a claim	9	
	Confidence	5	

PSTs made mathematics their own and felt empowered through them to act against or within different situations. This sentiment of empowerment is perfectly captured in one of the PSTs' reflections:

This task helped me realize that I can do more than I give myself credit for. It also taught me that I can use mathematics to solve very important questions. I can use this task at a board meeting in the future if they are discussing teacher pay. It is going to help me solve other problems by having a better attitude towards the future task.

PSTs working with this modeling task reported engagement, which helped them deepen their mathematical understanding. Out of the 26 PSTs reporting agency, 12 of them discussed a high level of engagement and enjoyment, and 11 of them stated that they gained a deeper mathematical understanding. This deeper understanding is not limited to mathematical modeling but also extends to more general ideas such as proportions, percentage decreases and increases, and statistics. The engagement and richer mathematical understanding are well captured in one of the PSTs' reflections:

As big advocates for livable wages in general and as future teachers, we have found this task to be useful for engaging in meaningful conversation that may lead to increased teacher pay. By analyzing data on a problem that is near-and-dear to our hearts (i.e., teacher pay), we felt more engaged with the research and have a better understanding of statistics in math.

This modeling task was also empowering and enjoyable for PSTs. This sense of power achieved through mathematics is also evidence of the level of mathematical confidence PSTs gained after this task. Specifically, five PSTs explicitly stated that this task helped them improve their confidence for future modeling tasks, and some related the empowerment they experienced to their future classroom. One PST stated,

I've also learned that I think it's valuable to show students from a young age how powerful mathematics is. Many students dislike math but I think it's partially because they don't have a firm grasp on how they can benefit from it. As a future educator I want to include math modeling in my classroom so students can start to see how beneficial math is to them and start to realize they are capable of changing so many things just through math. As for my mathematical self, I've learned that I really do enjoy math and get excited about the power it gives us to educate others and learn more every day.

These examples of engagement, enjoyment, confidence, and deeper mathematical understanding are ultimately a

result of the relevance this task had for PSTs. Almost all of the PSTs reporting agency (22 out of 26) stated that this task was relevant both as teachers and at a personal level. PSTs thought the task was relevant because it "brings the math that we will be teaching our future students into a real-life context," and it served them as "a great example of how you can use real-world data to study statistics and answer statistical questions." On a personal level, almost all of the 22 PSTs stated that this task was useful in informing future decisions in their lives and empowering them as members of society.

Implications and Conclusions

This study contributes to the growing body of research that mathematical modeling, and specifically SJMM, is a powerful practice for PSTs. First, similar to prior findings (Aguirre et al., 2019; Jung & Wickstrom, 2023), SJMM is a tool that allows PSTs to build greater awareness of social issues, critique existing systems, engage in rich mathematical reasoning, and investigate contexts that are relevant to their students and local communities. All PSTs in our study demonstrated reflection and gained a better understanding of teacher pay from multiple perspectives. They were also able to question their own beliefs and assumptions. We demonstrate that there are several contributions from this study and task that push our field forward, including task design, empowerment, and connections between modeling and analysis.

Remember that we situated our work with PSTs within the realistic (Pollak, 2007, 2016) and socio-critical (Barbosa, 2006) perspectives of modeling. We did this because we wanted PSTs to experience modeling as a tool for life and feel empowered to explore and critique societal structures through mathematics (Barbosa, 2009). From our findings, we argue that the nature of the SJMM task matters. When designing this task, we considered (a) issues that are important to PSTs, (b) issues where they can envision themselves as agents of change, and (c) issues where they have background knowledge. Even though we set out with this goal, we did not anticipate how much PSTs would connect with this task on a personal and emotional level and the ways in which it allowed them to explore and reflect on societal structures in relation to their own awareness of the problem. With respect to reflection, 18 of 28 PSTs discussed their emotions about what they found, and nine reflected on their choice to become a teacher. Related to this, the mathematical findings from their models took on additional importance. Twenty out of 28 PSTs demonstrated action and discussed how their findings might affect their future life choices and ways in which they could advocate for themselves and others. Our results highlight that tasks that are part of PSTs' lived experience not only help them to become

better modelers and mathematicians but also help them become better informed members of society by giving them mathematical tools to act within an existing societal structure.

The second way our work pushes the field forward is by highlighting how empowering mathematical modeling can be and the ways in which it can foster agency. Almost all PSTs (26/28) demonstrated agency. They enjoyed being able to take the content they had learned (i.e., statistics or ratio and proportion) and consider how it could be used in a real-world setting that was relevant to them. Some enjoyed the task and learning more about the situation, and others reflected on how powerful it was to have mathematics as a tool to back a claim. Modeling was an experience that allowed them to experience mathematics in positive and purposeful ways, which is important because, as we noted earlier, PSTs often have low self-efficacy related to mathematics (Bursal & Paznokas, 2006; Emenaker, 1996). Our task highlights how a task that is important to PSTs helps them to feel empowered and to use mathematics as a tool for expressing ideas. Many PSTs also projected these ideas into their future classrooms and envisioned ways they might help students feel empowered by mathematics.

Lastly, our work highlights how the process of mathematical modeling is a tool that can promote analysis. When PSTs modeled, they had to consider different assumptions, variables, and perspectives on fairness. When they created their model, it gave them a starting point that represented an ideal version of life as a teacher. Across models, many only considered first-year teachers, and they wondered how additions to their model (e.g., dependents, health care costs) might impact their findings. Pondering how their models might be revised and refined helped to further understand and critique existing societal structures.

Overall, our study emphasizes the benefits of mathematical modeling in developing PSTs as mathematical thinkers and informed decision makers. It also illuminates how modeling can be a tool to promote dispositions across critical consciousness. From this work, we hope other mathematics teacher educators are inspired to add to the conversation and propose new SJMM tasks. This will allow us to continue to consider the ways in which SJMM tasks connect to PSTs' experiences, grow their critical consciousness, and help them develop into informed citizens.

Statements and Declarations

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Appendix

Is Teacher Pay Fair?

Purpose of the Problem/Rationale: In this modeling problem, preservice teachers (PSTs) are asked to reflect on teacher pay to determine if teachers are fairly compensated. We have included three different perspectives, of many, that PSTs might consider when investigating this topic. These perspectives include:

- **Historical Perspective:** We provided a table that documents teacher pay across time by decade compared with other spending items (i.e. house, car, food). In this part of the modeling task, the intent is for PSTs to draw on knowledge of fractions and percentages to be able to appropriately compare spending across time. PSTs also have the opportunity to consider ratios and unit rates as they consider how much teachers would be paid if pay increased in ways similar to other spending items.
- **Cost of Living Perspective:** We also open up the problem for PSTs to consider if starting salaries in their area are appropriate. We anticipate that the open nature of this question could lead down several different paths including mapping out typical spending in relation to salary to see if it is appropriate and/or mapping out time and effort teachers are paid for. When venturing down each of these paths, PSTs could rely on fractions to illustrate ideal spending habits and to map out time and effort.
- **Comparison Perspective:** Paired with the cost of living perspective, some PSTs might want to compare teachers' salaries with other occupations that they deem "similar". From this perspective, they may rely on percentages to compare other occupation's salaries with teacher salaries.

****Instructor Note**** - We realize we have provided many resources for this problem. Please choose the perspectives that you have time for and that seem most relevant. The instructor can focus on this problem such that PSTs are instructed to view the problem through one particular perspective or all three perspectives can be introduced and investigated. We have done both and have found either pathway to be productive and empowering for PSTs.

Target Mathematical Topics:

- Defining and working with fractions and percentages
- Ratios and unit rates
- Percent increases and decreases
- Statistics and Data Visualization

Target Modeling Type:

- Description - The purpose of this task is to help PSTs see modeling as a tool that allows them to describe and make claims about a situation at hand. (This task could also be predictive if PSTs are asked to determine what teacher pay might look like in 10 years.)

Learning Goals:

- Given different quantities, construct fractions and compare them to reason about the data.
- Identify potential unit rates and what they mean in terms of a context.
- Compare the qualities of quantities in two different ratios.
- For ratio views as A parts to B parts use the values A/B and B/a to make multiplicative comparisons between total amounts.
- Graph relationships in the coordinate plane.
- Calculate percent increase and percent decrease in several different ways, and explain why the calculation methods make sense.
- Analyze data sets.

Materials and Supplies:

- Cost of Living Table (see the end of this document)
- Websites are provided throughout the lesson plan.

Instructor

Introduction

****If PSTs are new to modeling, the instructor might want to begin with a discussion of what modeling is and let PSTs know that we are in the initial phase of the modeling cycle where we are exploring a situation and considering how we can use mathematics to make sense of the issues.****

Preservice Teachers (PSTs)

PSTs will spend this time discussing the two questions. We anticipate PSTs will bring up factors such as (time, stress, number of students, and pay).

Time

5–10 minutes discussing factors that cause teachers to change professions.

****This part of the lesson is optional. We chose national articles and data for the lesson plan, but, during enactment, we also drew on local teacher pay data and articles for PSTs to consider.****

Prior to class, PSTs will be asked to read an article on teacher stress and factors they consider when leaving the profession.

(<https://www.cnbc.com/2019/08/09/50percent-of-teachers-surveyed-say-theyve-considered-quitting-teaching.html>)

The instructor will introduce the problem by showing two videos and telling the PSTs a little about the videos.

There are different perspectives on teacher pay. In the first video, we will hear from a middle school teacher, Laney, and her financial challenges as a teacher. In the second video clip, we will hear about a study where the general public is unsure about teachers' pay - highlighting two different perspectives.

Laney's Story: <https://www.youtube.com/watch?v=Oitog-P5TZM&t=1s>

Money article: <https://money.com/teachers-average-salary-underpaid-poll/>

- What are factors that go into teachers' decisions to change careers?
- What are ways we can better support teachers in their work?

Next, the instructor orients students to the issue of teacher pay. **"Recently teachers have been striking across the country advocating for higher wages while others argue that teachers are paid a fair salary. Imagine you are working for your state government or a local teacher's union in charge of adjusting teacher pay. How much do you think new teachers should be paid? Is their pay fair?"**

The instructor asks the students to brainstorm and record answers in a Google doc to the following questions:

- What do you want to know more about to evaluate this claim?
- What will you consider in making your decision?
- What tools will help you?

****As PSTs work on Part 1, the instructor may need to search for any additional tools that PSTs request and the instructor agrees are important in constructing the model.****

After students have recorded notes for each bullet, the groups will share out. This part of the process is very helpful for PSTs in conceptualizing their models.

Additional Resources

The Teacher Salary Project: <http://teachersalaryproject.org/>

Teacher Pay Fact vs. Fiction: <http://www.nea.org/home/12661.htm>

Notes from the Classroom (what to anticipate and discuss):

- Expect that PSTs might want/need access to other information, like minimum wage or access to other profession's salaries across the time period to develop their case.
- Each time we have enacted this, the PSTs brought the 3 different perspectives to light. Emphasize and connect to their wonderings as you proceed into the three perspectives.
- We found that PSTs need time to look at the data holistically. Sometimes, they only wanted to compare two data points. It is important to ask them how the data changes over time and visuals and tools that could be helpful to them.

We anticipate PSTs will spend this time considering factors that go into teacher pay (time spent at work, level of education, number of students, years of experience, cost of living) and how to determine a fair wage (comparison to other occupations, cost of living).

Approximately 20 minutes.
We anticipate 10-15 for PSTs to work and jot down ideas and 5-10 for groups to share out ideas.

Part 1: Perspectives on Pay

Perspective 1: Historical Perspective on Teacher Pay and Cost of Living

****If PSTs are new to modeling, the instructor might want to begin with a discussion that we are mathematicizing the situation by mapping our problem into the mathematical world.****

To explore the issue of teacher pay we are going to examine a couple of different perspectives that you, as a class, raised. In the end, you are the researchers, so if there are other tools, resources, or data you want to draw on or share, please do!

One way that we could consider the problem is to compare the cost of a teacher's needs to the average salary. In other words, has the average teacher salary kept up with things that they might want or need to buy?"

The instructor introduces the table (see attachment) and states "The table below shows teacher salaries in comparison to the cost of living and items that they might need. Consider teachers' salaries in relation to cost of living."

The instructor introduces

- What do you notice?
- What information and/or recommendations can you draw from this table?
 - To get at fraction knowledge, the instructor might ask a question like, "If pay followed the same trends in relation to other spending items as in 1930, how much would teachers be paid in today's dollars?" or "Are there ways we could adjust the table to better compare trends from year-to-year?"
 - To focus on ratio/proportion, the instructor might ask: "How would you expect the data to behave over time, why?" "Can you map out other tables that might seem reasonable? Why do they seem reasonable to you?"
- Are there other factors we have left off the table that you think are important to investigate and consider?

After the PSTs engage in discussion surrounding their strategies and bullet point 3, return to the question, is teacher pay fair?

Perspective 2 and 3: Current Cost of Living and Comparison to Other Occupations

****If PSTs are new to modeling, the instructor might want to begin with a discussion that as a class we have now come to understand teacher pay from a historical perspective but there are other ways we could explore teacher pay. What is a fair wage if we consider present costs? How is it determined?***

We anticipate PSTs might do the following.

- Look at growth across each element in the table. For example: How many times bigger is teacher pay now than in 1930?
- Create a graph to capture the data points.
- Determine what fraction or percentage each element is of teacher pay over time.

As the instructor, it is important to make these ideas public to the entire classroom.

We believe the two most important questions to get the PSTs reasoning about fair wages and mathematics "Are there ways we could adjust the table to better compare trends from year-to-year?" and "How would you expect the data to behave?" Here, we want PSTs to talk about ways to modify the data to make it easier to compare and understand as well as different rates of change within the table.

We anticipate PSTs to notice that teacher pay has not increased at the same rate as other expenses. We also anticipate them discussing other factors like student debt that are part of cost of living now and weren't in earlier decades.

We anticipate PSTs to wonder if this is true across all occupations, not just for teachers.

We anticipate this activity will take 30–40 minutes. 20–30 minutes of work time and observations. 10–15 minutes of discussion and PSTs reporting out

PSTs might request/discuss the following information and they brainstorm these two perspectives (and most is contained in the links to the left):

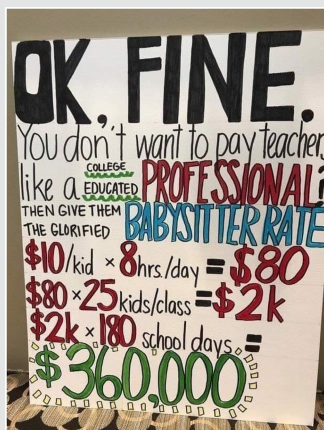
20–25 minutes

The instructor might say, "Now that you have examined teacher pay in relation to the cost of living, broadly, let's consider local pay and if it is a fair wage in your area as well as factors that determine pay."

Another way that we can consider teachers' starting pay is to consider it in relation to other degrees and their starting salaries.

- How does the average starting pay for a degree in education compare to other degrees?
- What do you notice and wonder about in the data?

<https://www.visualcapitalist.com/visualizing-salaries-college-degrees/>



**You can let PSTs choose what grain size (local, state, or national) pay they would like to consider. We have found in our enactments that PSTs tend to want to investigate state or local pay."

(Instructor or teacher would select their own area) The current starting salary in Bozeman, Montana for a new teacher with a Bachelor's degree is \$41,586.

- Is this salary appropriate? How do we determine if a salary is appropriate?
- What factors do you think go into calculating this salary?
 - Time spent on the job
 - Cost of living
 - Level of Education
 - Comparison to other jobs
 - Tax Revenue

To help us understand the cost of living, one tool that we can draw on is the Living Wage Data Base. <https://livingwage.mit.edu/counties/30031>.

- This database provides suggested wages for people in particular areas to live.
- The instructor asks, "How could you use the Living Wage Data Base to investigate if teachers' pay is fair?" Different school districts have discussed different types of compensation modeling for teachers.

What do you want to know more about to make this decision?

- Cost of living
- Cost of education
- Job responsibilities & their associated economic values
- Employment benefits beyond yearly salaries (i.e. health insurance, retirement plans)
- Comparable wages of other employment options
- Use of teacher salaries to perform job duties.

PSTs might pose questions like:

- How does the teacher salary compare to what is needed to live?
- Are there other factors we should consider that are not listed in the living wage data?
- How accurate is the living wage data? Is there another tool we could utilize?

Part 2: Envisioning the Model: *The purpose of this component of the lesson is for PSTs to begin vetting ideas as they begin to construct their model.*

“The starting salary in (your town) is (enter salary here). (For example, the starting teacher salary in Bozeman, Montana is \$41,586. Your task is to determine if teacher pay is fair and make a recommendation on how much new teachers should be paid in your area.”

The instructor transitions to focus PSTs’ attention on the construction of the model. The instructor might say something like: “We are in the phase of the modeling cycle where we are constructing the model. Drawing on the three perspectives, and others, consider how you will make a determination if teacher pay is fair.”

At this point, the instructor encourages PSTs to begin constructing their model focusing on and having groups record the following questions:

- What assumptions are you making in order to create your model?
- What do you think are important factors to consider? Why?
- What factors are you not considering? Why?
- What are important variables and numbers to consider? Which ones do you think will change and which will remain constant?
- What choices are you making? Why do they seem appropriate in the situation?
- What resources will you use to inform your model? Why?

After PSTs have had time to brainstorm, we have found that it is very helpful to allow them to share their ideas and have other PSTs ask questions briefly.

The PSTs begin to work in pairs or groups to begin developing their model and drafting a plan of action.

PSTs begin to sketch their model considering how they will create a model to propose how much teachers should be paid and recording ideas in a Google doc or shared space.

Part 3: Developing the Model: *In this phase, PSTs are developing the model.*

As the PSTs work, the instructor circulates the room listening in on strategies and helping PSTs as needed.

- What pictures or graphs might help people understand your model?
- What mathematics does your model rely on? How did you use mathematics to describe the situation and solve your problem

PSTs will complete a write-up of the solution and a descriptive write-up of their processes. (please see handout for directions to give to PSTs).

This work can take place in the classroom (20 minutes) or given outside of class so students have additional work time. Giving them this as homework seems to work best.

Part 4: Assessing the Model/Getting Feedback: *In this phase of the lesson, PSTs are getting feedback from peers to help them consider revisions they might make to their model.*

****If** PSTs are new to modeling, the instructor might mention that we are in the revising part of the modeling cycle. Our purpose is to look at what we have done so far to consider if it meets our needs or needs to be revised further.*

The instructor arranges the PSTs so that two groups of modelers are paired together. The instructor asks each of the pairs to evaluate the other teams’ model considering the following questions:

- How does the model work? How does the model address the needs of the situation?
- What are the strengths of the model?
- Are there situations where you can identify the model falling short?
- Are there ways that the model could be improved or revised to best meet the needs of the situation?

PSTs take time to read the other group’s report and answer each of the questions.

This work can be done in class or for homework. We suggest that PSTs have time to talk with each other and provide feedback in person.

Notes from the Classroom (what to anticipate and discuss):

PSTs drew on the information presented in different ways. Here are different types of models you might encounter and helpful feedback.

- **Historical and Cost of Living:** PSTs compare teachers' pay to another item (like housing price) to look at what percentage of pay the item took up over time. *Feedback:* This seems to focus on inflation. In what ways does inflation relate to fair pay?
- **Cost of Living:** PSTs look at different variables (children, living with roommates, student debt) in relation to current teacher pay in the state or city. *Feedback:* Consider what happens when we change some of the variables. Under what conditions is teacher pay fair? Are these conditions realistic? What is an appropriate amount of pay to live off of?
- **Comparison and Historical Perspective:** PSTs compare teacher pay to other salaries (engineer, nurse, nanny) to examine pay over time. They might also focus on the number of hours worked a week or a year. *Feedback:* Have PSTs consider how other professions are paid (private companies vs. government funding). Are there other reasons that professions (like nursing) might be paid more than teachers?

Part 5: Refining the Model/Reporting Out: Ideally, this phase should be done publicly so students can share their models with one another.

The instructor has each of the groups present their models. PSTs can also create short PowerPoint videos to be posted online. After PSTs present it can also be interesting for the instructor to ask about similarities and differences between models and things the groups appreciated about one another's work.

PSTs will present their ideas by sharing their model, the process they went through in designing the model, and why it meets the needs of the situation.

20 minutes.

Part 6: Relating to the Process as a Learner (Optional)

After PSTs have completed the modeling task, the instructor will take time to consider what aspects of the modeling process they envision using in their future classrooms. This might include:

- Describing how this modeling task was similar or different to other modeling tasks they have completed.
- What was the purpose of the model and what questions did it help us to answer?
- What mathematics did you employ to help you construct your model?
- The theme of this modeling task was fairness, in what ways did you make decisions about what was fair in the task?
- In this task we used mathematics to help us describe a situation and make predictions. What opportunities do you see to explore these themes in the K-6 curriculum? What could this look like in your classroom?
- What were pivotal moments in this task for you? What were the challenging moments? Why?

The purpose of this model was to consider if teacher pay was fair. We encourage the instructor to first debrief about the theme of fairness and how we can explore fairness from different perspectives.

Next, it is important for students to draw direct connections to the K-6 classroom. Have them discuss possible scenarios in K-6 classroom and/or read suggested materials from the K-6 resources area. K-6 ideas might include:

- Saving money when buying an item at a store.
- Inflation

Sample Resources

National Average Data

Year	Cost					
	Home Price	Gallon of Gas	Cost of New Car	Loaf of Bread	Hamburger Meat (per pound)	Teacher Salary (per year)
1930	\$3,845	10 cents	\$600	9 cents	12 cents	\$1,420
1960	\$12,700	25 cents	\$2,600.00	22 cents	45 cents	\$5,000
1970	\$23,450.00	36 cents	\$3,450.00	25 cents	70 cents	\$9,268
1980	\$68,700.00	\$1.19	\$7,200.00	50 cents	99 cents	\$17,644
1990	\$123,000.0	\$1.34	16,950.00	70 cents	89 cents	\$33,034
2008	\$238,880	\$2.05	\$27,958	\$2.79	\$3.99	\$53,910
2013	\$289,500	\$3.80	\$31,352	\$1.98	\$4.68	\$56,886
2018	\$383,500	\$2.50	\$35,742	\$2.50	\$4.02	\$60,483

Teacher Salary by State and Qualifications <https://www.nea.org/resource-library/educator-pay-and-student-spending-how-does-your-state-rank>

Examples of PST Models

Model #1: Historical and Comparison Perspective

Referencing the historical data table, this group **defined** that teacher pay was fair if it kept up with the cost of living across time. In the first draft of their model, they wondered if they could assume that teacher pay was fair in 1920, the table's starting value. If teacher pay was not fair in 1920, even if it kept up with the cost of other items, it would still not be fair and this would affect how they interpret the data across time. They decided that they needed to draw on other essential occupations (e.g., teachers and engineers) to compare teacher pay to as markers of fairness. They were very motivated to engage in this problem to better understand their future pay.

To **research and brainstorm** the situation, they searched the internet for the average pay of engineers and nurses across time. As they researched these occupations, they noticed interesting patterns across professions and wondered why engineers have always been paid the most while teachers and nurses pay reverses across time. They critiqued whether differences in pay were connected to gender pay disparity.

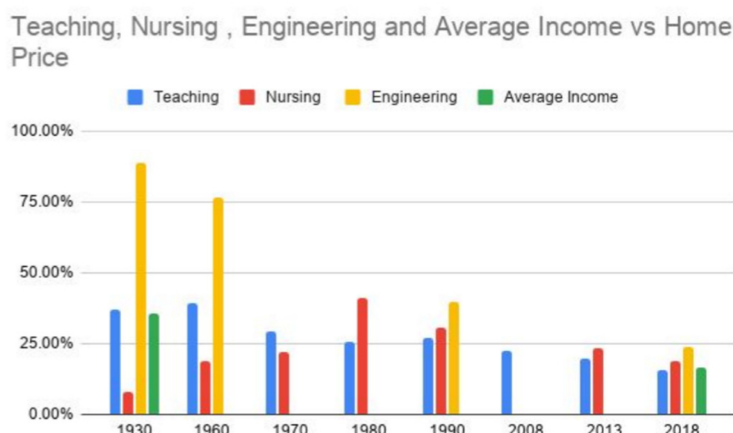
They decided to **build a model** comparing pay to the cost of an item across time and **identified variables** of home price and gas price as the two most important markers in the table to compare pay to. They **assumed** that teacher pay should increase at the same rate as these markers, if it is fair, and that the data they collected was accurate. In describing these two markers they state:

We felt that home price was a good variable to consider because we could compare the increase of home price to increase of teacher pay over the years. This helped us show that teacher salaries do not keep up with the cost of living. . . We also used percent increase of gas price compared to percent increase of salaries for nurses, engineers, and teachers. Gas price is a very important factor to consider because it always fluctuates with inflation. It is a good baseline to use to determine how much the price of important items changed over the years.

This group used mathematics to create two different models. In their first model (see Figure 1), they thought about home price as their whole or 100%. They looked at each profession's income as a fraction of the average home price.

Wage to Home Price Comparison Visual

Where 100% equals the total home price. This shows that engineers always had a larger amount of home price. It is also showing that nurses have increased and then decreased over time. Teacher pay to home price has decreased over time. This is showing that while other jobs are sticking more with the inflation of home price, teachers have gradually kept declining meaning eventually teachers will not be able to afford a home if inflation keeps progressing and teacher pay keeps at the rate it's going.



In **describing the visual and getting a solution**, they stated,

We concluded that over the years none of the jobs we looked at are keeping up with the inflation of home price, but especially teacher pay.

The group created a second model in which they compared the price of gas and pay across salaries in 1990 to 2018 and calculated a percent increase or decrease. They showed that gasoline had increased about 87% and nursing pay and engineering pay had increased at rates at or above the increase of gas. Teacher pay was below the increase of gasoline at 83% (see Figure 2).

- Increase of price of gas from 1990 to 2018 – $2.50/1.34 = 1.866 \times 100 = 186.6 - 100 = 86.6\%$
 - Increase of teacher pay from 1990 to 2018 – $60483/33034 = 1.831 \times 100 = 183.1 - 100 = 83.1\%$
 - Increase of nursing pay from 1990 to 2018 -- $71730/37738 = 1.901 \times 100 = 190.1 - 100 = 90.1\%$
 - Increase of engineering pay from 1990 to 2018 -- $91030/48832 = 1.864 \times 100 = 186.4 - 100 = 86.4\%$

In **getting a solution** and describing their findings they stated,

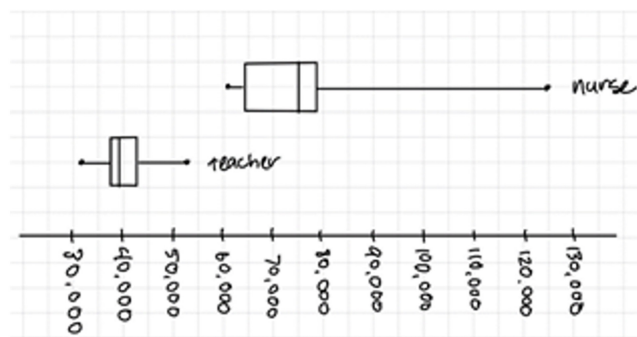
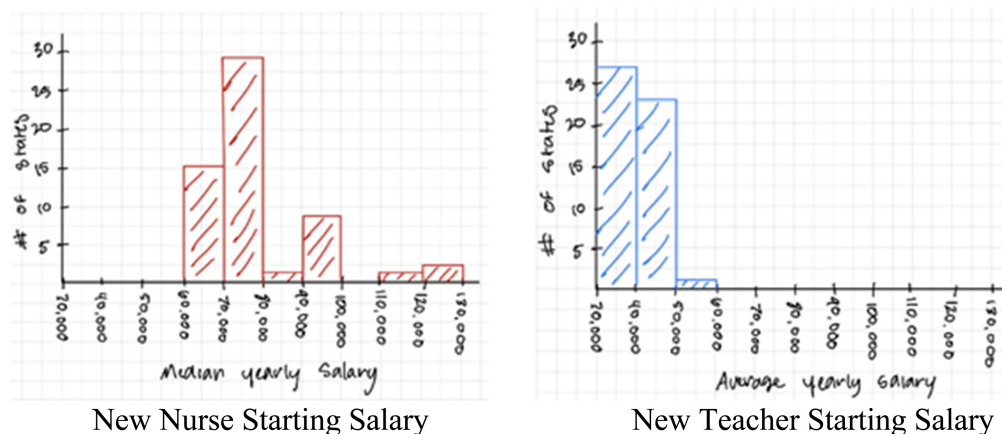
Our math helped us determine that over the years until 2018, the percent increase of pay was higher for all jobs than the percent increase of gas. In 1990 to 2018, the percent increase of teacher pay was 3% lower than the percent increase of gas prices. Since the price of gas increased more than teacher pay, we can conclude that teacher pay is not staying consistent with inflation, meaning that teacher pay is not fair. In order for us to be able to deem it as fair, the inflation of pay must be the same or higher than the inflation of gas.

Model #2: Comparison Perspective

After pondering the question “Is teacher pay fair?”, this group decided to approach it from a statistical perspective, since they decided to search for data and were expecting variability in this data. They started **researching and brainstorming** ideas on how to conceptualize fairness in this context, create their model accordingly, and collect data. Ultimately, this group decided to compare teacher salaries to nurses’ salaries and found a data set containing the median starting salary of registered nurses with an associate degree in each state (which they found on the internet), and they compared this to another data set containing the average teacher pay in each state (which was provided by the instructor). They **defined** that teacher pay was fair if the pay of teachers was comparable to other occupations with similar degree requirements, like nurses. They decided to focus on new teacher and nurse salary data across states.

When thinking about the limitations of their model, they expanded on their data collection methods and stated that “neither website gives too much information on how they collected their samples, so we cannot assume any bias in

the data collection". In other words, this group **assumed** this data was collected randomly and was therefore unbiased. To conduct their data analysis, this group created histograms and boxplots corresponding to each data set.



Box Plot Comparing Nurse and Teacher Starting Salary by State

After observing these distributions, they **built their model** by calculating multiple measures of center for both data sets and found that the mean and median salaries of nurses are a lot higher than the mean and median salaries of teachers, respectively. They noticed in their boxplots that the nurse salaries data set contained an outlier, and thus decided to ultimately use the median as their better measure of center. This group then focused on measures of dispersion in both data sets and calculated the interquartile range only, as they realized the absolute mean deviation was not a good measure of spread because of the presence of possible outliers: "We also decided not to calculate the MAD because the nursing salary data includes an outlier, and the MAD would be affected by that outlier. In this case, the IQR is a more accurate representation of the data."

Once they had these measures of center and spread, this group noticed that nurses' salaries have a greater dispersion than teacher salaries by stating: "The IQRs, \$5,793 for teachers and \$14,400 for nurses, show that nurses' starting salaries have a much greater dispersion between states. Teachers starting salaries across the US have a much smaller range than nurses starting salaries."

Afterwards, they started to interpret their results and **get a solution** in the context of the problem and decided to focus on the state of (State):

If you were a first-year teacher in this state, you would make about \$32,871 per year. The yearly cost of living in the state is \$47,887. That means without a secondary form of income, teachers would be \$15,000 short of being able to live comfortably. . . .having to pay off four years' worth of student loan debt that could vary based on what school you went to or different scholarship opportunities you had as a teacher. The average student loan debt for a four-year degree is \$34,100. Having to pay off debt is impossible when you make \$4,000–\$15,000 less than the cost of living in your state."

Finally, after analyzing and interpreting their results, they concluded that teacher pay is not fair when compared to nurses' salaries.