REAL-WORLD CRITICAL MATHEMATICS LESSON: A WAY TO LEVERAGE STUDENTS' CONCEPTUAL UNDERSTANDING AND SOCIOPOLITICAL AWARENESS

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We investigated the development of students' sociopolitical consciousness via engagement in a mathematical activity purposefully designed around understanding the unemployment rate in the US. Qualitative data was collected from 12 university seniors participating in an online capstone class. Results showed that students: (1) further developed interpreting data visualizations, (2) understood the nature of the unemployment rate in the United States (i.e. how data is collected, how it is calculated, and how it behaves over time), (3) developed an understanding of the inequality in the US social and political structure, and (4) developed a more critical lens or more critical consciousness by questioning and critiquing the status quo. This study shows that the Unemployment Rate task can be implemented to bridge the disconnect between the mathematics classroom and real-world applications, and may eventually affect a "liberatory social change".

Keywords: Data Analysis and Statistics, Design Experiments; Equity, Inclusion, and Diversity; Social Justice

As we move beyond the Equity principle, which provides access to high-quality mathematics instruction to all students from different backgrounds (National Council of Teachers of Mathematics (NCTM), 2000) and move towards "recognizing that inequitable learning opportunities can exist in any setting, diverse or homogenous" (NCTM, 2000, p. 60), we no longer only strive for "mathematics lessons that only focus on the important mathematics" (NCTM, 2000, p. 15). Brantlinger (2013) critiqued the NTCM standards ten years ago that they were not enough to provide equal access to marginalized groups of students. As we move toward the recent years, NTCM in their Access and Equity series of books, they are not only including ensuring that all students should have equal to high quality access (Berlin & Berry III, 2018) but also attend to students' cultural background, knowledge and experiences (Musgrove & Willey, 2018). Furthermore, Gutstein (2018) leveraged NTCM's *Principles to Actions* to make a shift toward using mathematics to examine societal structure and empower students to take actions against these power dynamics. Coinciding with the North American Chapter of the International Group for the Psychology of Mathematics Education's Equity Statement (2019), they recognized that mathematics is not a neutral subject but rather subjective to a human's perspective. Thus, a mathematics lesson that disregards the students' perspective, experience and cultural background does not equally support all students (Melhuish et al., 2022). Hence, we demand that mathematics lessons not only support mathematical concepts and provide an equitable and inclusive environment but should also promote practical, relevant knowledge and, importantly, develop students' critical mathematics consciousness.

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This study is contained in a larger study of 12 university seniors participating in an online capstone class, Mathematics and Society. We aim to examine:

1. How do students' critical mathematics consciousness and sociopolitical awareness develop through a real-world critical mathematics lesson exploring the unemployment rate in the United States?
2. How do students use mathematics and the topic of this lesson to deepen their understanding of the world?

Theoretical Orientation

From Critical Consciousness to Critical Mathematics Consciousness

In Paolo Freire's (1970) Pedagogy of the Oppressed, he defined critical consciousness as the ability to be aware of the oppression within the political, social, and economic system and to therefore take action against any forms of oppression. Researchers further narrowed it down to critical mathematics consciousness. For this study, we positioned ourselves in line with Register and colleagues' (2021) Critical Mathematics Consciousness Theoretical framework. Register and colleagues (2021) noticed that students' critical mathematics agency is the triangulation between Ethical Mathematics Awareness, Sociopolitical Mathematics Awareness, and Communitative Mathematics Awareness. This framework attends to three aspects: (1) that mathematics is a tool to represent real-world information by itself and can disparage or liberate certain groups in society, (2) that mathematics carries biases since it is a human activity, and (3) that mathematics can be used to inform or misinform society (Register et al., 2021). We also used Stephan et al.'s (2021) Critical Mathematics Consciousness Growth framework. Stephan and colleagues' (2021) framework boiled down to six levels of mathematical consciousness. First, *intransitive*, where students believe that the cause of the disposition is due to luck or higher being; hence, the situation cannot be changed. Second, *dysconscious*, where students blame the victims for fault and perceive that it is the victim's own responsibility to act. Third, *disempowered*, where students notice either an individual or dominant group is the cause for the oppression, but have no ability to change the situation. Fourth, *isolated semi-transitive*, where students believe the inequality takes place in some isolated incidents and can only act within these situations. Fifth, *systemic semi-transitive*, where students recognize the pervasiveness within the system of oppression, but are not yet ready to act. Lastly and sixth, *critical transitive*, where students acknowledge the pervasiveness of the oppression within our social structure and acquire the critical agency to emancipate the power of oppression (Stephan et al., 2021).

Figure 1 is our reenvisioning of Stephan et al.'s (2021) Critical Mathematics Consciousness Growth framework, where the highest stairstep corresponds with the first level of their framework and it steps downwards to the bottom, sixth level - which then connects to the open door and exits to the level of critical mathematics consciousness. Similar to Freire (1973), where he noticed that the critical consciousness is flexible within a situated environment, Stephan and colleagues (2021) also acknowledged that these Critical Mathematics Consciousness levels are context-dependent, and are not a strictly hierarchical order that students can achieve. Thus, these stairsteps would occur depending on the context of the situation and only if students choose to review it during their reflection or conversation. Some stairsteps may be skipped over.

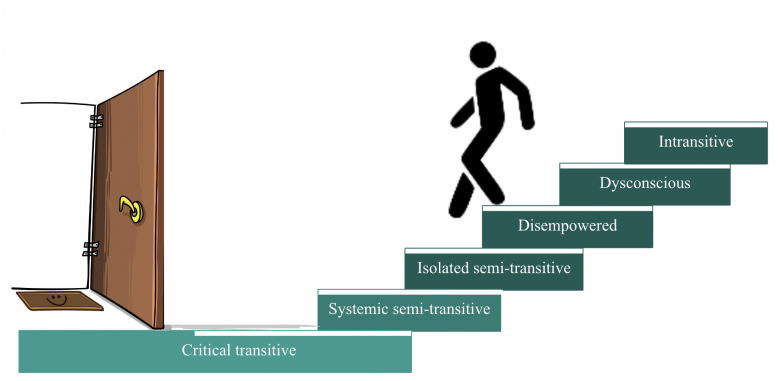

Figure 1: Reenvisioning of Stephan et al.'s (2021) Critical Mathematics Consciousness Growth Framework [Photo credit: Creozavr from Shutterstock.com]

From the Meaning of Knowledge to the Definition of Mathematics

Here, we take up our view of knowledge as the relativist whose view, particularly for mathematics, is a justified belief, is context dependent, and is socially-situated within human language (Ernest, 1991). Coinciding with social constructivist view and subjective knowledge, we believe that mathematics knowledge is co-constructed through a community and it is constantly shared and negotiated among members of the community (Ernest, 1991). Thus, instead of breaking our data down to individual students, we used Stephan et al.'s (2021) Critical Mathematics Consciousness Growth framework to analyze the community's knowledge through group discussion and interaction.

Furthermore, our meaning of mathematics has moved beyond the traditional definition of mathematics as numbers, quantities and logic (Heid, 2010) and has shifted toward mathematics as social community interactions within a sociopolitical context (Wagner, 2017). Therefore, we explored our data utilizing Thanheiser's (2023) three-part framework for the meaning of mathematics: (1) logical connections between abstract concepts and quantities, (2) a language to represent the natural order of reality and (3) human interactions that are flexible to one's sociopolitical position.

Methods

We drew data from design-based research (Bakker & van Eerde, 2015) where a US Unemployment Rate lesson was introduced to a group of 12 university seniors who participated in an online capstone class, Mathematics and Society. The lesson was covered over a two-session (110 min/session) span including pre-homework with a survey and post-homework with a survey, consisting of two main tasks which required students to (1) investigate unemployment rate data across racial groups from March 2019 to March 2022 and (2) establish through research the causes for the gaps in the unemployment rates among racial groups. It can be found at https://tinyurl.com/UERlesson. The Unemployment Rate lesson was developed and modified to serve students' sociopolitical and traditional mathematics goals. The sociopolitical mathematics goal was to aid students' knowledge of the unemployment rate, especially during the spike of the Covid-19 pandemic, and students' discovery of the inequality in the unemployment rate among racial groups. At the same time, our traditional mathematics goal was for students to understand how the unemployment rate was calculated, how to visually represent the given data, compare the data across time, interpret the visual representation, and connect it to current events. Videos

and transcripts were collected and transcribed throughout the two sessions with one main coder and one advisory coder. Through thematic analysis, we read students' responses during group discussion, reduced them to codes, then later collapsed them into common themes (Creswell, 2014) and let the story arise naturally through those themes. We later applied Stephan and colleagues' (2021) Critical Mathematics Consciousness Growth framework to students' responses through an interpretive method. We categorized each statement using the six levels of the framework. If the statements did not fall in any of the categories, we tagged them as inconclusive. Counting each time a student made a statement during group discussions as 1, we were able to quantify the number of responses during discussions in two tasks and create percentages for each of the six levels.

Findings

Below we will answer (1) how students' critical mathematics consciousness and sociopolitical awareness developed through a real-world critical mathematics lesson exploring the unemployment rate in the United States and (2) how students used mathematics and the topic of this lesson to deepen their understanding of the world.

How Students' Critical Mathematics Consciousness and Sociopolitical Awareness Developed Through a Real-World Critical Mathematics Lesson Exploring the Unemployment Rate in the United States

Task 1. As part of task 1, raw data from the Bureau of Labor Statistics website (at https://tinyurl.com/UERdata) were presented to students with informational videos of how the data was collected (see https://tinyurl.com/UERvideo for an example of one of these videos). Along with Figure 2, students were asked to examine the graph of the unemployment rate over a period of three years during the pandemic. Students expressed concern about the integrity of the data by questioning the motivations of the data-collectors and the uncounted population. For

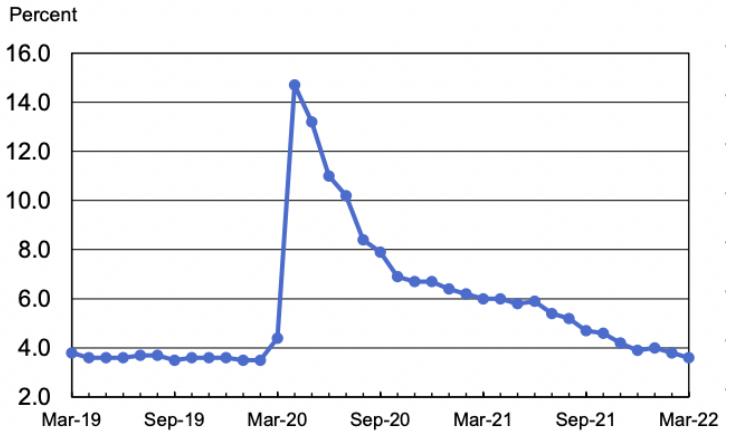

Figure 2: The US unemployment rate from March 2019 to March 2022

example, a student commented, "I notice that the system for collecting unemployment numbers is vague and lacks robustness. I wonder about the mechanisms and motivations for the people who conduct unemployment statistics." Here we coded this response as *concerning the data* and put it under *questioning-motivation of data collectors*. Another student added, "How does the BLS (Bureau of Labor Statistics) account for individuals working under-the-table, and also

underemployment?" We labeled this response as *questioning-the uncounted population* under the same category as *concerning the data* code.

Students were then asked to compute the unemployment rates for White, Black, Asian, and Hispanic groups of population. For example, in the Asian population, students used the number of unemployed Asian workers divided by the number of Asian civilian labor force. As students moved further into modeling these rates using graphs and charts, they focused much of their discussion on making connections between the data (graphs, unemployment rates, etc.) and the events that happened during those times. Comments such as "... the fact that everything changes good or bad pretty much at the same time, you know the event wasn't racist, but the systemic racism is how it affected how how high or low they went up at the ground… *"* or "significant disparity between racial groups, Black unemployment rate is almost double the White unemployment rate" occurred more often. For the two previous statements, we coded them as *noticing the disparity* with a subcode as *systematic racism*. They noticed the disparity between racial groups which negatively impacted the Black, Indigenous, and People-of-Color populations; recognized the existence of systemic racism in our social structure; and made an implication that systemic racism might be a causative factor for this disparity.

Next, students worked on populating the unemployment rate by racial groups across time and used visual graphs to represent the information. Figure 3 was one example of the graphs on the unemployment rate from Mar. 2019 to March 2022. When students examined the data and the graph, especially observing the spike of the unemployment rate during the full

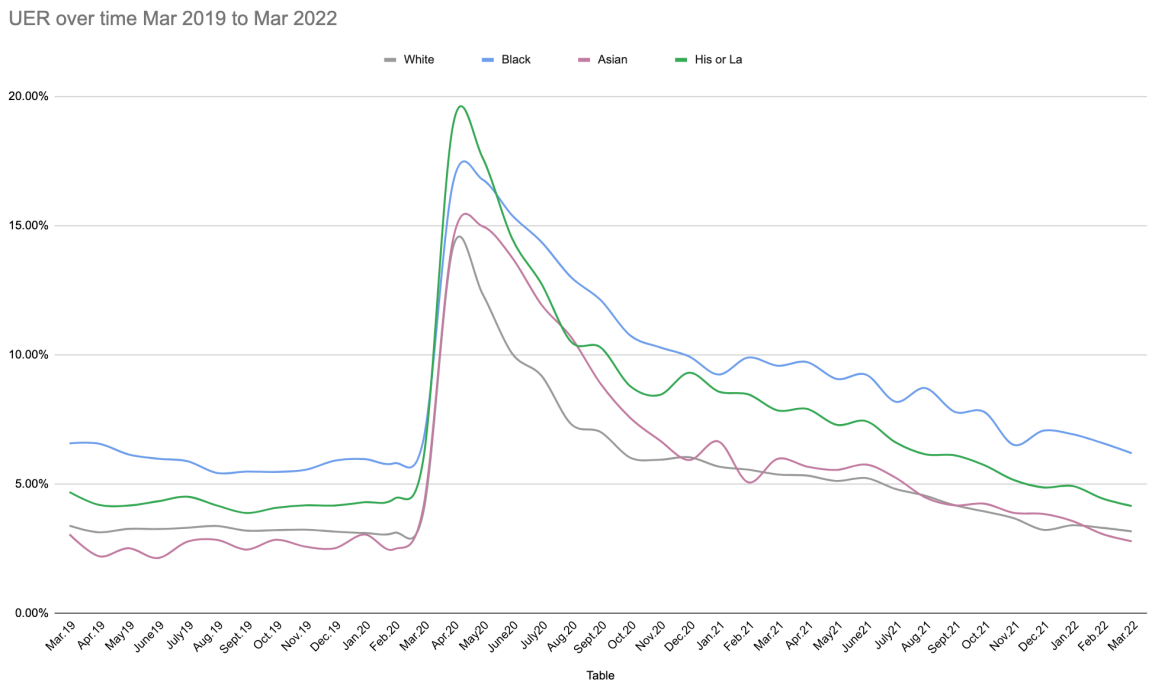

Figure 3: The US unemployment rate from March 2019 to March 2022 according to racial groups

government shutdown period of 2020, they noticed, *"...* we wanted to see the comparison between before the pandemic hit and where we were looking at and that's exactly what we just saw is the pre-pandemic unemployment rates. So this everything is higher.*"* Students not only reasoned how real-world events impacted the behavior of the data (graphs),

> Massive spike after Covid hit. Asian population most heavily affected relatively, not particularly surprising considering the prevalence anti-Asian rhetoric and the sentiment it caused. Asian unemployment rate slower to recover to pre-pandemic levels relative to other groups. Hispanic/Latino hit the hardest at the start of the pandemic, but it recovered faster relative to other groups, quickly falling below black unemployment rate.

They also explored which factors they needed to gain further insight on using the data, "I would like industry chart numbers…like you could even see movement between industries, and I think that would be really helpful to give further insight." The three previous statements were coded as *connection between world events and mathematics*.

Task 2. As part of task 2, students did research based on their interest topic to investigate the reason for the disparity. The three topics such as how discriminatory hiring practices, the inequity in education opportunities, and the underemployment impacted the racial differences in the unemployment, were chosen. When doing their research, one group noticed:

> We found that there's a negative correlation between the level of education at school and the unemployment number. The more education, the less unemployment. The dropout rates over a period of like 93 to 2014 so see that includes astronomically high at 33% and the Black is at 50%, which is also really high and then over time they came down to where Black is within 2% of White and Hispanic is still like double everyone else, they have much, much lower. So that there's been improvement over time in those in those categories.

We noticed that students used traditional mathematics such as comparing the percentages of high school dropout rate among racial groups to justify their sociopolitical mathematics such as the higher the level of education resulted in the lower unemployment rate. With the statement above, we labeled it as *justification for socio-awareness* code. As students moved further into their research, investigating the causes for the disparities among racial groups, their conversations became more reflective and they started to discuss possible practices to combat forms of oppression and criticized practices that perpetuate oppression. One student discussed the hiring practice of removing applicants' names from resumes to reduce bias based on name:

> This is not like this is just kind of like individual thing by individual companies, so there isn't like a you know, like a like a joint effort from like a group of companies so. I guess there's two trying to do something to kind of get rid of the discrimination, you know, like the bias to were like Black job applicants, but for the most part, I think the effort is really limited.

For this response, we coded as *socio-action*.

Applying the Critical Mathematics Consciousness Growth Framework to students' responses in task 1 and task 2 (Percentage Breakdown). Through the Critical Mathematics Consciousness Growth framework (see Figure 1), during task 1 group discussion, 35% of students' statements were coded at *disempowered* level. For example, students made statements such as, "The unemployment rate among non-white population is higher than that of White population, especially for Black and Hispanic populations" or "It definitely seems like it hit different groups differently, which is really interesting." These responses let us know that the inequity happened to certain groups of the population, but we had yet to know if students had any action plan to combat this disparity. As we looked further, around 4% of the statements were at *systemic semi-transitive* level. For example, students commented, "we've talked about how

like people's labor and the ability to work is related to their skill and their ability and not their race, so these. These numbers would kind of highlight systemic racism like we've been talking about…" Students recognized the pervasiveness of the inequality; however, they had not yet expressed the desire to act. No other level was recorded during this discussion. We noticed students' *disempowered* and *systemic semi-transitive* level statements happened more at the beginning of the discussion, however, they diminished as students dug deeper into traditional mathematics and used more technical language to analyze the behavior of the graphs.

During the task 2 group discussion, 58% of the students' statements were at *semi-transitive* level, 33% were at *critical transitive* level, 8% were at *disempowered* level and the rest were inconclusive. As students moved toward the end of task 2, the *critical transitive* level statements started to show up more in the discussion. Students demonstrated their knowledge of the pervasiveness of the systemic racism in our society and they acquired the agency for understanding how they could act against the displaced oppression. For example, one student reflected:

> We have data from the government, we could totally use this data to to regulate these corporations that have no regulation … every administration, independent of the party, keeps giving them more lax and more rope that we get hung on.

In this case, students acknowledged that they had the power to influence the government to impose regulations on the corporations in question and they were willing to do so.

How Students Use Mathematics to Deepen Their Understanding of the World

Lastly, in order to investigate how students use mathematics to deepen their understanding of the world, we identified students' mathematics actions, such as concretely using numeric data and visually interpreting graph behavior by correlating it with events that occurred in real life. Furthermore, they expanded their knowledge by effectively utilizing visual graphs to represent information. Table 1 lists some of the students' mathematics actions and correlates them with their responses.

Table 1: Sample of Students' Mathematical Actions and Corresponding Responses

Sample of the students' mathematical actions throughout the tasks	Sample of students' responses
Concretely using evidence through data to justify how Covid 19 pandemic causes the high unemployment rate	..we wanted to see the comparison between before the pandemic it and where we were looking at and that's exactly what we just saw is the pre pandemic unemployment rates so this everything is higher.
Comparing data/math overtime or across timeline	The string a few others is big bend on the downhill slope until I realized that that was one of our data points…
Predicting the causes/reasons for the behavior of the graph	And how more affluent employees, whether they're white or Asian or more skilled workers might have had more savings and more ability to

	take the less desirable job or live off of the out of the workforce off of their savings when everybody was sent home and so.
Understand the strength and weakness of visual graphs	…our initial graph of the representation of employment was a scatter plot and we concluded that it like puts an emphasis on each individual month and each individual discrete case and there's less of an emphasis on trends….

Discussion

As we implemented the tasks, students were initially showing the *disempowered* level in which they recognized the disparity between unemployment rates among the racial groups. However, they did not offer any concrete social action to promote equality. As we moved further through the lessons, students displaced the *systemic semi-transitive* level in which they identified the systemic racism in our society as one of the causing factors for this discrepancy, but a practical plan was not yet formed. It was during task 2 that students provided some solutions, such as influencing government regulation. In addition, students noticed that they have the power to make an impact on the current situation. Finally, through our observation of students' mathematics actions, they used mathematics to expand their understanding of the world by analyzing both numeric and visual data and further correlating them with real-life situations.

Through this lesson of real-world critical mathematics, we could observe students' critical consciousness as it surfaced. Although it took quite a strenuous process and arduous time for collecting data and planning out the sequence of the tasks, we successfully contributed a real-world critical mathematics lesson that contained practical mathematics knowledge and promoted students' critical consciousness through sociopolitical mathematics awareness. When mathematics tasks are purposefully designed around a current critical issue that is affecting students' lives and highlighting the oppression in our current socio-political structure, we support students in developing a meaningful understanding of their world and creating a space for them to have meaningful sociopolitical *and* mathematical discussions. As Gutiérrez (2013) argued, "In that sense, taking the sociopolitical turn is a necessary chapter in mathematics education," (p 60).

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