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ARTICLE TITLE:

Developing Equity Literacy and Critical Statistical Literacy in Secondary

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DIGITAL OBJECT IDENTIFIER: 10.5951/MTE.2021.0015

VOLUME: 11

ISSUE NUMBER: 1

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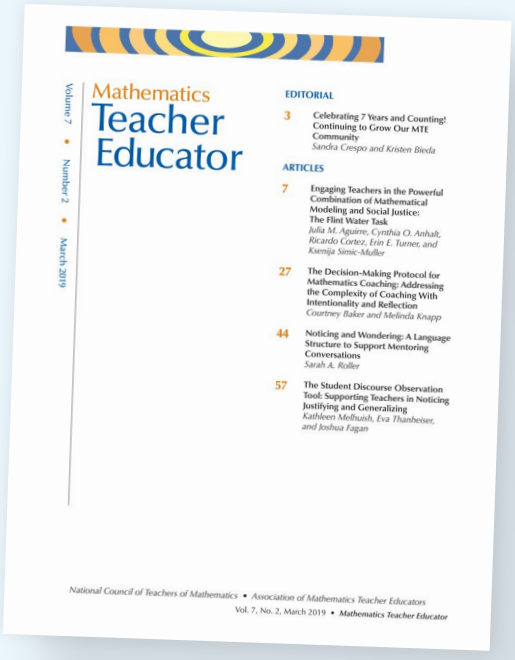

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Developing Equity Literacy and Critical Statistical Literacy in Secondary Mathematics Preservice Teachers

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There is a lack of teacher education materials that develop equity literacy in content courses for preservice secondary mathematics teachers. In response, we created teacher education curriculum materials for introductory statistics that include an integrated focus on developing equity literacy and critical statistical literacy. In this article, we provide an overview of our materials' design along with a detailed look at one activity regarding racial demographics and tracking in high school STEM courses. We present evidence regarding the positive impact of these materials on the teacher candidates' competency, value, and likelihood of applying their equity literacy and critical statistical literacy. Implications for mathematics teacher educators working to develop equity literacy together with content knowledge are discussed.

Keywords: Preservice teacher education; Equity; Statistics

The Association of Mathematics Teacher Educators' *Standards for Preparing Teachers of Mathematics* (*SPTM*) (2017) begin with a fundamental assumption: "Ensuring the success of each and every learner requires a deep, integrated focus on equity in every program that prepares teachers of mathematics" (p. 1). Mathematics teacher preparation built on this assumption should attend to developing the equity literacy (Gorski, 2013, 2018, 2020) of mathematics preservice teachers (PSTs) in a meaningful way throughout their program (Association of Mathematics Teacher Educators [AMTE], 2017), including in the content courses they take. However, there is a lack of teacher education materials available to support development of secondary (grades 6–12) mathematics PSTs' equity literacy in content courses. We addressed this problem of practice by creating teacher education curriculum materials for introductory statistics content courses that help develop equity literacy for secondary mathematics PSTs. The study of statistics can be meaningfully integrated with development of equity literacy through careful selection of contexts and associated data sets to investigate. Additionally, development of teachers' critical statistical literacy, concerning their ability to analytically examine and critique sociopolitical statistical content to inform action or change, also provides a natural and important way to connect the learning of statistics with equity literacy. The purpose of this article is to share information about these statistics teacher education curriculum materials along with evidence of their impact on mathematics teacher candidates' competency, value, and likelihood of applying their equity literacy and critical statistical literacy.

Recent teacher preparation standards (e.g., AMTE, 2017) and statements by professional mathematics organizations (e.g., NCSM & TODOS, 2016; NCTM, 2018) have emphasized the importance of developing mathematics teachers who work toward an equitable education for all students. We adopt Gutiérrez's (2007) "working definition" of equity as "being unable to predict students' mathematics achievement and participation based solely upon characteristics such as race, class, ethnicity, gender, beliefs, and proficiency in the dominant language" (p. 41). It is our position that equity in education requires an explicitly antiracist approach (TODOS: Mathematics for All, 2020), and that liberation of Black and Brown children is an important goal of education in general (Martin, 2015; TODOS: Mathematics for All, 2020) and statistics education in particular. The tools and methods of statistics can be used to counter destructive narratives involving race, gender, poverty, and many other sociopolitical issues and build insight regarding desperately needed changes to existing institutions and systems. It is important to us that our statistics teacher education curriculum materials help equip PSTs with the skills they need to serve their future students.

Relevant Literature

In this section, we describe two constructs in which we grounded our work when creating new statistics teacher education curriculum materials: equity literacy and critical statistical literacy.

Equity Literacy

We chose to adopt Gorski's (2013; 2018) framework regarding equity literacy for educators to guide our efforts when creating statistics teacher education materials that

work toward this goal. The equity literacy framework outlines the skills and dispositions that educators need in order to create and sustain equitable learning environments for students as well as educating students about equity. The framework's identification and detailed description of key skills and dispositions to develop in educators and its compatibility with the *SPTM* made this framework particularly useful for our work.

Equity literacy is built on two foundational goals: (a) commitment to furthering understanding of how equity and inequity manifest in both organizations and society; (b) individual and institutional expertise, skills, and desire to identify and eliminate inequities while actively working toward equity. According to Gorski, development of equity-literate educators should begin by cultivating the following abilities: recognize biases and inequalities, including those that are subtle and those they hold themselves; respond to biases and inequities in the immediate term through actions like fostering conversations with colleagues about equity concerns in the school or intervening when biases or inequities arise in the classroom; redress biases and inequities in the long term, which could include teaching about equity-related issues like poverty or advocating for school practices that are equitable; create and sustain a bias-free and equitable learning environment through approaches such as expressing high expectations for all students, considering the resources available to students outside of school when assigning homework, and cultivating a supporting classroom environment for all students.

Study of the development of equity-literate secondary (grades 6–12) mathematics PSTs has illuminated important considerations for mathematics teacher educators working at the course level. Mintos et al. (2019) studied five secondary mathematics teacher education programs and found that secondary mathematics PSTs' opportunities to learn about equity literacy-related topics in their coursework focused on microscenarios and exploration of teacher candidates' own identities rather than systemic issues of equity. They also concluded that integration of learning opportunities that promote equity literacy throughout the courses in secondary mathematics teacher preparation programs is not happening yet. Gallivan (2017) and Aguirre et al. (2019) brought attention to mathematics tasks, particularly the need to develop mathematics PSTs' abilities to choose and implement culturally relevant or social justice-based tasks. Roth McDuffie et al. (2014) highlighted how useful the analysis of representations of practice can be for supporting PSTs' noticing of equitable teaching practices. Collectively, this research informed our design of the statistics teacher education curriculum materials overall as well as how to develop teachers' equity literacy and what topics to address in the activities within the curriculum materials.

Critical Statistical Literacy

Statistical literacy and its components have been an important topic in statistics education for some time. Wallman (1993) proposed that statistical literacy be defined as the ability to understand and critically evaluate statistical results that permeate daily life along with an appreciation of contributions that statistical thinking can make in professional and personal decisions. Others built on his work to further expand the meaning of statistical literacy. Gal's (2002) model of statistical literacy for adults focused on the reading of statistical information, data-related arguments, or stochastic phenomena, and has been widely accepted by the field. His model includes five knowledge elements (literacy skills, statistical knowledge, mathematical knowledge, context knowledge, and critical questions) along with two dispositional elements (beliefs and attitudes along with critical stance). Recently, scholars (Bailey & McCulloch, 2019; Weiland, 2017) built on ideas from critical theory and critical literacy to propose the new construct of *critical statistical literacy*, which means the practice of analytically examining and assessing sociopolitical statistical content to inform action or change. Here, statistical content can refer to data or anything that uses data-based arguments, such as news articles, scientific reports, or legislation. Similar to enactment of critical theory and critical literacy, a key emphasis in *critical statistical literacy* is the application of statistical literacy skills to *lead toward action or movement for change*. This is where we found an organic connection to the work of an equity literate educator, and thus we determined that attending to secondary mathematics PSTs' development of critical statistical literacy in a statistics course was a meaningful way for us to tie development of their equity literacy into the work that occurs in a statistics content course.

Our work sought to answer the following research questions:

Does use of our statistics teacher education curriculum materials improve secondary mathematics PSTs' competence, value, and likelihood of applying their

(a) equity literacy?
(b) critical statistical literacy?

Description of Materials

Our *MODULE(S2): Statistics for Secondary Mathematics Teaching* curriculum (Casey et al., 2019) was written for MODULE(S^2), an NSF-funded project that created secondary mathematics teacher education curriculum materials that develop mathematical knowledge in and for teaching (Hill et al., 2008; Rowland et al., 2016). The materials are freely available at www.modules2.com. The MODULE(S^2) statistics curriculum is organized into three modules, which

if taught together would fill a semester-long, modern introductory statistics course that is aligned with recommendations in the American Statistical Association's *Statistical Education of Teachers* report (Franklin et al., 2015). The materials are written in an active-learning workbook format with prompts for PSTs to answer as they complete in-class activities. The topics for each module are as follows:

Module 1: Study Design and Exploratory Data Analysis
Module 2: Statistical Inference (hypothesis tests and confidence intervals)
Module 3: Statistical Association (quantitative and categorical)

Throughout each module, we take an integrated approach to developing PSTs' knowledge of statistics (including their critical statistical literacy), pedagogical knowledge for teaching statistics, and their equity literacy. In this article, we focus on how our materials provide opportunities for developing secondary mathematics PSTs' equity literacy and critical statistical literacy.

Along with the equity literacy framework and critical statistical literacy construct, AMTE's *SPTM* also informed our selection of the knowledge and skills our materials would focus upon. While working to advance their knowledge of statistical content (*SPTM* Indicator C.1.1) and the process of conducting a statistical investigation (*SPTM* Indicator C.1.2), we also wanted to devote ample attention to *SPTM* Standard C.4: Social Contexts of Mathematics Teaching and Learning through attending to its five indicators (AMTE, 2017):

- C.4.1: Provide Access and Advancement
- C.4.2: Cultivate Positive Mathematical Identities
- C.4.3: Draw on Students' Mathematical Strengths
- C.4.4: Understand Power and Privilege in the History of Mathematics Education
- C.4.5: Enact Ethical Practice for Advocacy

The investigations in our modules aim to develop PSTs' understandings of the role of access and advancement in mathematics education and the important position they play in changing access and advancement in mathematics education in the future (*SPTM* Indicator C.4.1). By promoting PSTs' enactment of active learning, especially with statistics projects that inform action both now and with their future students, our modules help PSTs learn how to promote positive mathematical identities (*SPTM* Indicator C.4.2). Our materials also encourage drawing on students' strengths, such as using community knowledge (Gutstein, 2006) in selecting project topics (*SPTM* Indicator C.4.3). They help PSTs to understand the role of power and privilege in the history of mathematics education (*SPTM* Indicator C.4.4) through statistical investigations into topics like school funding, school closings, and gifted program admissions. Through developing PSTs' critical statistical literacy, our materials equip PSTs to use statistics as they advocate for themselves and their students (*SPTM* Indicator C.4.5). Purposeful attention to developing PSTs' understanding of the complexity of equity-related work, including the meaning of the term equity, undergirds this work. For instance, in Module 1, the PSTs take an anonymous survey that includes a multiple choice question regarding what equity means to them. The question choices are different historically based definitions of equity that have been used in various movements in America since 1900. A follow-up class discussion is enacted to educate them about these historical definitions of equity, to show them their classmates may bring other beliefs about equity to their work, and to better articulate their own beliefs about equity.

Throughout the activities, a strand considers the potential causes of income inequality in America and links with racism, including consideration of potential causes that (according to stereotypes) originate from *within* the group(s) that ends up less wealthy and potential causes that originate *outside* of the group(s). We chose this topic since it encompasses central themes in U.S. society now and throughout history. It also aligns with the *SPTM* call for examining issues of equity, in education and in general, since educational opportunities are linked with race and income in U.S. society. As PSTs work through the activities in this strand, they investigate data that speak to a number of these potential causes (e.g., differing values of education, K–12 class sizes) and keep returning to the question of what are true causes of differences in incomes of different racial groups in America. Multiple aspects of education in general and mathematics education in particular are addressed, aligned with the *SPTM* Indicator C.4.4. This prolonged examination of the issues around income and educational inequalities allows for the development of a complex understanding of them by PSTs, which supports their becoming equity-literate educators who engage in meaningful conversations concerning these topics in their future workplaces. At every step, we take care to avoid accidentally reinforcing stereotypes. We also present a balanced mix of "reading the world with mathematics" (examining the current situation) and "writing the world with mathematics" (leading to action or change, per application of their critical statistical literacy) (Gutstein, 2006). Although any individual activity could be used in a general-education introductory statistics course, it is the totality of them that makes them specific to the work of mathematics teacher education. **Appendix A** lists our materials' activities related to equity literacy and critical statistical literacy along with statistical topics and *SPTM* C.4 indicators they address. Across these activities, we intentionally provoke conversations about equity from multiple angles, including individual factors such as teachers' implicit bias, institutional factors such as tracking, and societal issues such as systemic racism.

Each of our noted activities typically has three sections: preactivity exercises, in-class activity, and postactivity exercises. The preactivity exercises prepare the PSTs for the activity by asking them to read some text, watch a video, or engage in a short task concerning the context or issue that the activity considers. Understanding of factors relevant to the context of a dataset is critical for analytical examination of it; hence, this is an important step in the process of developing PSTs' capabilities for applying critical statistical literacy to the equity-related contexts in the materials. Personal reflection is also incorporated into the preactivity exercises to personally connect the PSTs to the contexts and provide opportunities for recognition of biases they may hold themselves or instances where they were involved in inequitable practices, contributing to development of their equity literacy. Next, the classroom portion of each activity presents tasks which actively engage PSTs in a data-based statistical investigation set in a context that brings out issues of equity. Depending on the investigation, the PSTs may be engaged in any or all of the phases of the statistical problem-solving process (Bargagliotti et al., 2020): formulating statistical investigative questions, collecting or considering data, analyzing data, or interpreting the results. The activities purposefully present questions that prompt PSTs to make or explore conjectures. For instance, when interpreting the results of a statistical analysis, there is an emphasis on prompting PSTs to make contextually based conclusions along with conjectures regarding why the identified phenomenon is occurring. The identified reasons in the class activities relate back to biases and inequalities, constructs that equity-literate teachers need to learn to recognize and discuss thoughtfully. The in-class portion of the activities conclude with class discussions that bring out key statistical concepts as well as important understandings regarding the social contexts of mathematics teaching and learning. Here, the development of critical statistical literacy and equity literacy is often intertwined: PSTs learn how to use their statistical investigation to recognize, respond to, and address biases and inequalities. Finally, each activity has postactivity follow-up exercises calling for the PSTs to build on what they learned in the in-class activity. This includes an opportunity to reflect on what they learned in the investigation and connect it to the strand of investigations that address income, education, and race in the United States, furthering their understanding of the factors that contribute to income and educational inequality. To provide insight on how these components work together, we provide detailed information about an activity in our materials below.

Activity Example: Racial Demographics of U.S. High School Mathematics and Science Courses

Activity 11 of Module 1 of our statistics materials examines the racial demographics of U.S. high school mathematics and science courses in the 2015–2016 academic year. We have made minor changes to the phrasing in the activity for the purposes of this article.

Preactivity Exercises

Preparation for Activity 11 begins with exercises to be completed in advance of the class session where the activity will be enacted. As for many equity literacy-focused activities, these preactivity exercises deepen PSTs' understanding of factors relevant to the data's context and encourage personal reflection. The first preactivity exercise for Activity 11 focuses on two important factors regarding the racial composition of U.S. high school mathematics and science courses: teacher expectations and tracking in mathematics courses. PSTs watch videos that explain each factor and recent research findings concerning its impact on student learning, then answer questions including "Do you have an experience where you felt your teacher was biased against you or, maybe, favored you in some way?" and "Why do you think tracking results in lower overall achievement than detracking-plus-new-teaching-methods for students in these different studies?" An additional preactivity exercise has PSTs read about a framework concerning students' graph comprehension; different frameworks are read by different small groups of PSTs.

In-Class Activity

Activity 11 focuses on frameworks to describe students' graph comprehension and application of one of the frameworks to a graph concerning the racial demographics of U.S. high school mathematics and science courses; an excerpt of the student materials for Activity 11 is in **Appendix B**. The activity begins with each small group preparing then delivering a short presentation to the class on their assigned framework. The Levels of Graph Comprehension Framework, based on Curcio's (1987) work, is the only relevant framework for the present discussion. It focuses on the idea that different types of questions can be asked about a graph to enact different levels (reading the data, reading between the data, reading beyond the data) of graph comprehension; descriptions of these levels are included in **Appendix B**.

The next portion of the activity engages PSTs in the final two phases of the statistical problem-solving process (Bargagliotti et al., 2020): analyzing data and interpreting the results. PSTs are given a graph displaying the racial breakdown of U.S. high school students enrolled in math and science courses in 2015–2016 along with the racial composition of U.S. high schools overall. Question 11-b prompts the PSTs to apply the Levels of Graph Comprehension Framework to the graph, writing and answering at least one question at each of the three levels of the framework. Question 11-c asks them to consider possible connections between educational tracking practices and

the data presented in the graph. Instructors are encouraged to have PSTs answer the questions themselves then discuss their responses, first in small groups then as a whole class. This approach offers multiple opportunities for PSTs to grapple with the important ideas of this activity: first individually, then with a small number of people, followed by the whole class.

Documentation of the enactment of this activity in three undergraduate Statistics for Teachers courses offered at mid-sized regional universities provides insight into how PSTs respond to this portion of the activity. Many PSTs begin by working to understand the graph. Central to this work is recognizing that the first bar in the graph shows the racial breakdown of high school students in general and that comparison of the other bars to that bar is useful for analyzing the data. Next, they often focus on the two classes that differ most from the racial composition of high schools: Algebra 1 (grades 11–12) and calculus. Many of the PSTs choose to write and answer questions about these classes' compositions. Often, this work reveals the need for instructor support to correctly interpret the conditional percentages in these bars. For example, in one class a PST crafted a "reading the data" question to ask, "What is the percentage of Hispanics who are in calculus?" and stated the answer was 16%. The instructor noted this misinterpretation of the percentages in the graph was prevalent in the class members, and worked with them to understand that the aforementioned 16% is conditioned the other way: 16% of calculus students are Hispanic. The instructor followed this with a class discussion regarding approaches for discerning which variable is conditioned on in displays of conditional percentages and considerations when deciding which variable to condition on when working with raw data.

Discourse concerning "reading beyond the data" for this graph and responses to Question 11-c provide opportunities for making conjectures that call for courageous conversations (Singleton, 2021) concerning two factors that contribute to identified differences in the racial composition of U.S. high school mathematics and science courses: racial bias and educational practices like tracking. We use the term *courageous conversations* (Singleton, 2021) to describe this discourse because members of the U.S. society have been enculturated to not talk about race, so it takes some bravery for our PSTs to engage in these discussions. The preparation for the whole-class discussion by first asking PSTs to collect their individual thoughts then discuss them with a small group is intended to make these courageous conversations more approachable by the PSTs and more productive overall.

In all three Statistics for Teachers courses, whole-class conversations about placement of students into mathematics and science courses addressed the role of mathematics teachers in this process. Some PSTs noted that implicit bias concerning race could be a factor in a teacher's course recommendations. In one course, the instructor led a conversation about the opportunities mathematics teachers have to recognize and respond to factors producing inequitable educational experiences. Noted opportunities included working toward an equitable process for making course recommendations for students and advocating for elimination of student tracking in mathematics. Enactments of this activity showed that it provides opportunities for PSTs to strengthen their abilities to recognize biases and inequalities (part of EL) and change their perspective regarding the relationship between race, tracking, and placement of students into their mathematics and science courses (part of critical statistical literacy).

Postactivity Exercises

Our materials also provide postactivity exercises; three such exercises for this excerpt of Activity 11 are provided in **Appendix C**. The first exercise develops PSTs' critical statistical literacy skills by prompting them to take action by designing statistical studies to investigate questions that may have emerged during the activity: Are tracking decisions influenced by the race of the student? What are the effects of tracking on students? It also builds PSTs' equity literacy by helping them consider a statistical study as a way to recognize and respond to probable biases in placement of students into their high school mathematics and science courses. The second exercise is an example of one of many in our materials that fit into the aforementioned strand of examining potential causes of income inequality in the United States, with an emphasis on causes related to education. When the strand begins in an earlier activity, the PSTs are asked to use a two-column T-chart to brainstorm possible causes of income inequality by race in the United States, with the first column listing possible within-group causes and the second column listing possible causes from outside of the group. Throughout our materials, PSTs are asked to reflect on data they have just analyzed then called to update their T-chart accordingly as part of their interpretation of the results. Here, the PSTs are asked to do so on the basis of their current thinking following completion of Activity 11, which brought out relevant issues of race, tracking in mathematics and science courses, and teacher expectations. Completing this reflective exercise builds their abilities to recognize biases and inequalities (part of EL) and perhaps alter their perspective regarding educational causes of income inequality by race in the United States (part of critical statistical literacy). The third exercise leads the PSTs through using school-level data to investigate race-related academic tracking. Completion

of this exercise builds both types of literacy for PSTs by helping them learn how to use publicly available data to investigate equity-related questions they may have about schools while recognizing limitations of the provided data (part b). Part c adds an important element to the enactment of critical statistical literacy relevant to reading beyond the data: considering the human experiences of the people studied to produce this data.

This detailed look into Activity 11 was intended to support a deeper understanding of the approach of the MODULE(S^2) statistics materials and how they work toward strengthening PSTs' critical statistical literacy and equity literacy. In the next section, we present research from implementation of the entire MODULE(S^2) statistics curriculum materials over the course of a semester.

Impact of the Use of the Materials

We conducted a research study to determine whether use of our materials improved secondary mathematics PSTs' valuing and likelihood of applying their equity literacy and their competence, valuing, and likelihood of applying their critical statistical literacy. The statistics materials have been piloted eight times at six institutions of higher education. These institutions include Research 1 universities and mid-sized regional universities. Seven of the eight piloting classes were dedicated Statistics for Teachers classes, whereas one was a statistics class for mixed majors. All sites used at least 75% of the materials, and most sites used all of the materials. Instructors at some sites taught the materials in face-to-face courses; others taught in a hybrid format (a mix of face-to-face and virtual synchronous meetings). All PSTs enrolled in piloting classes from spring 2020 through fall 2020 semesters were asked to participate. Thirty-four undergraduate secondary mathematics PSTs agreed to participate and provided data for this study. Approximately 70% of the participating PSTs were female, and the remaining 30% were male. The approximate racial composition of participants was 95% White, 3% Asian, and 2% Black.

Survey Description

In each piloting class, PSTs were administered an online survey at the beginning and end of the semester. Each PST was given a "study ID" number as an identifier instead of their name to keep responses anonymous but allow matching from pre to post. The expectancy-value theory of achievement motivation (Wigfield & Eccles, 2000) was used as the basis for the survey design. The theory states that a person is more likely to make choices that promote success at a target goal when they value the target and have confidence that they can succeed at achieving the target if they try. Expectancy refers to whether a person is likely to try to achieve their goal. The target goals for our study were application of critical statistical literacy and equity literacy. We adapted survey items from Banilower et al. (2013) and Markow et al. (2012) to write our survey items concerning teacher candidates' expectancy and value of critical statistical literacy and equity literacy; Tables 1 and 2 show the resulting survey items. Language for the equity literacy items came from AMTE's (2017) *SPTM* and Gorski's (2013) equity literacy framework, as noted in the source column in Table 2. For all Likert-scale items, the allowed responses were integers from 0 ("Not at all") to 5 ("Very much") except as noted. In addition, the end of semester survey included open-ended queries asking what PSTs learned and what was helpful for their learning concerning teaching statistics, equity and social justice, and critical

Table 1

Likert-Scale Survey Items Regarding Critical Statistical Literacy

Item number	Item
CSL1	Critical statistical literacy is the practice of analytically examining and critiquing statistical content (which could include datasets, news articles, scientific reports, or legislation) to inform action or change.
	What is your level of critical statistical literacy? (allowed responses of 0 to 5, with 0 being "low" and 5 being "high")
	Question stem: How well does this statement describe you?
CSL2	It is important to me to use critical statistical literacy skills when considering claims made regarding sociopolitical issues.
CSL3	I am likely to apply my critical statistical literacy to sociopolitical issues that I am interested in.
CSL4	I am likely to use activities regarding sociopolitical issues with my future students to help develop their critical statistical literacy. (Assume that you are teaching middle school/high school math students and your school setting is supportive of such work.)

Table 2

Likert-Scale Survey Items Regarding Equity Literacy and Their Sources

Item number	Item	Source
	Question stem: Suppose you are teaching middle school/high school math students. How well do these statements describe you? It is important to me to . . .	
EL1	. . . work to provide access and advancement to every student.	*SPTM* C.4.1
EL2	. . . express high expectations for all students through higher order pedagogies and curricula.	Gorski (2013); also aligned with *SPTM* C.2.1
EL3	. . . cultivate a classroom environment in which students feel free to express themselves openly and honestly.	Gorski (2013); also aligned with *SPTM* C.4.2
	Question stem: I am likely to . . .	
EL4	. . . engage in conversations with colleagues about bias and equity concerns in education.	Gorski (2013); also aligned with *SPTM* C.4.5
EL5	. . . challenge educational policies and practices grounded in deficit-based thinking about students.	*SPTM* C.4.3
EL6	. . . advocate for students by questioning existing educational systems and practices that produce inequitable learning experiences and outcomes.	Gorski (2013); also aligned with *SPTM* C.4.5

statistical literacy. All survey questions were reviewed by colleagues with expertise in evaluation and in equity literacy.

Data Analysis

Data analysis began by collating all participants' data into spreadsheets then transferring them into the statistical software R for further processing, matching responses from the beginning of the course (presurvey) and end of the course (postsurvey) using study IDs. Data from the Likert-scale items was only analyzed if the participant responded to both the presurvey and the postsurvey. Numerical and graphical analysis of the results on each of the Likert-scale items was done for the presurvey and postsurvey data, as well as changes from presurvey to postsurvey (post-minus-pre differences) to measure each individual's improvement. Some survey respondents did not answer every item, leading to sample size values that are reduced by 1 or 2 for some questions.

Analysis of responses to each of the open-ended survey items was done through open coding (Strauss and Corbin, 1990). The first author grouped the responses to each item according to themes in the data and gave names to the themes at two levels (grouping and subgrouping). The second author reviewed the coding, and then we discussed any coding the second author questioned to come to agreement on the final coding of the data.

Results

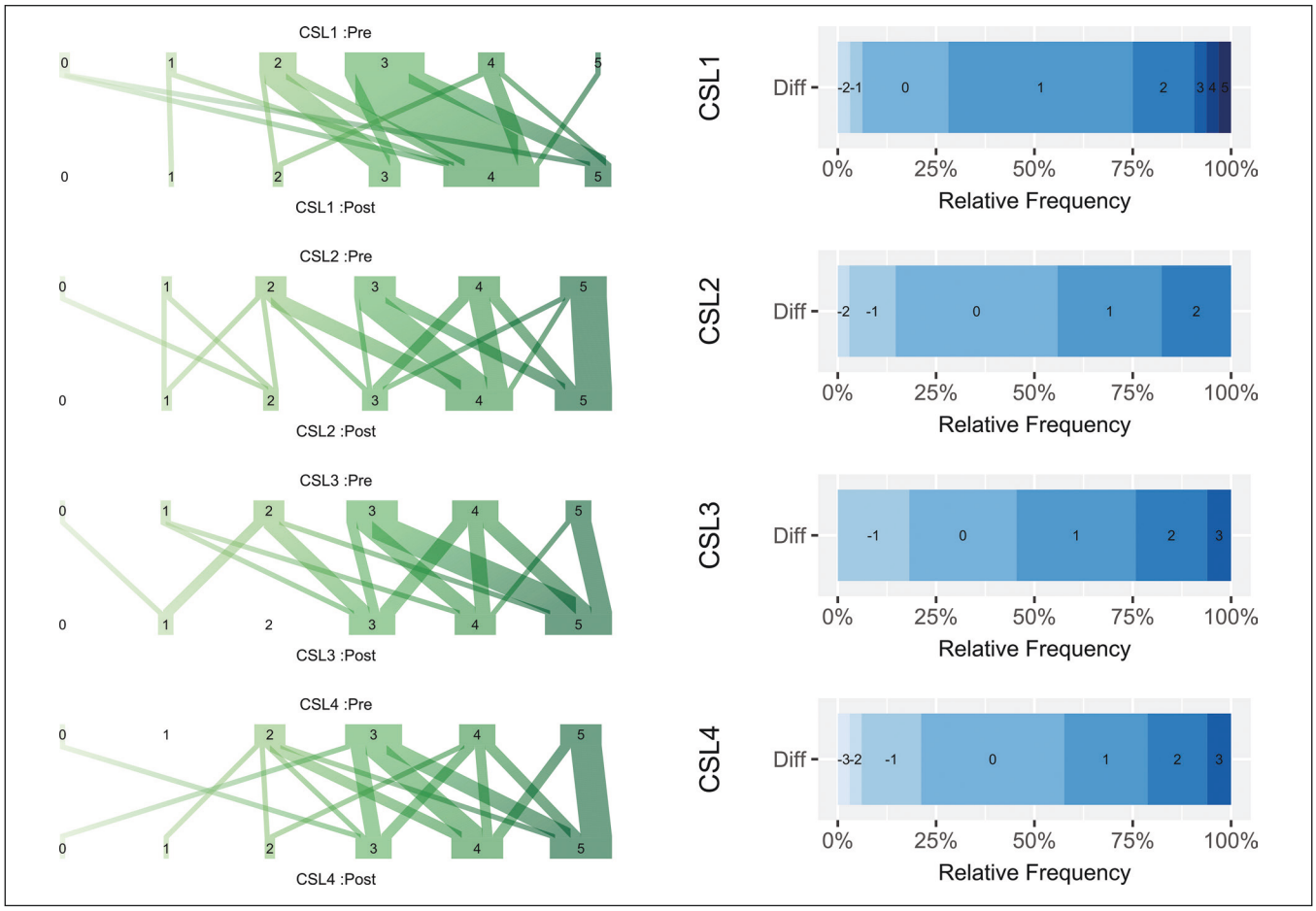
Results for Likert-Scale Items

Figure 1 shows the presurvey and postsurvey responses and changes for the survey items related to critical statistical literacy. For each survey item, the graph on the left shows the relative frequencies (using the thickness of the bands) of responses on the presurvey on the top row and the postsurvey on the bottom row. Movement of individual students' responses from presurvey to postsurvey are noted through the bands connecting the top to the bottom row, with the thickness of the band proportional to the number of students making that change (Weiner, 2021). Thus, the graphs on the left show overall improvement in items regarding critical statistical literacy: We want to see left-to-right movement of bands as we move from the top row of a graph to the bottom row, and that is the predominant feature that we see. For example, the largest diagonal band in the first critical statistical literacy graph on the left shows that almost all of the PSTs who had responded with a "3" on the presurvey subsequently responded with a "4" on the postsurvey, and that this was the most common result on this question.

The graphs in the right-hand column show the relative frequencies of the paired post-minus-pre differences, which are the number of categories that each PST moved, with a positive difference representing an increase in their rating. Each box is labeled with the value of the difference that it relates to. For example, in

Figure 1

Responses and Changes in Responses (Diff) to Items Regarding Critical Statistical Literacy



the first graph on the right side of Figure 1, the "1" band (meaning a change of +1 Likert-type scale response from pre to post) is the most common, with a size just under 50%; this band includes all of those PSTs whose response went from "3" to "4" (the diagonal band just mentioned), along with PSTs who went from "2" to "3," and "4" to "5."

The first critical statistical literacy question (CSL1), where PSTs self-assessed their critical statistical literacy level, showed a strong increase from the start of the semester to the end. A response of 3 was the most common at the start of the semester, but 4 was the most common response at the end of the semester. Additionally, the percentage of responses that were 3, 4, or 5 increased from 66% to 91%. For CSL2, the analogous percent increased from 74% to 85%; CSL3 similarly went from 73% to 91%, and CSL4 from 78% to 88%. Looking across all critical statistical literacy questions at the bands flowing from pre to post, we see moderate or strong positive movements, especially from 3 to 4 and 5, and from 2 to 3, 4, and 5.

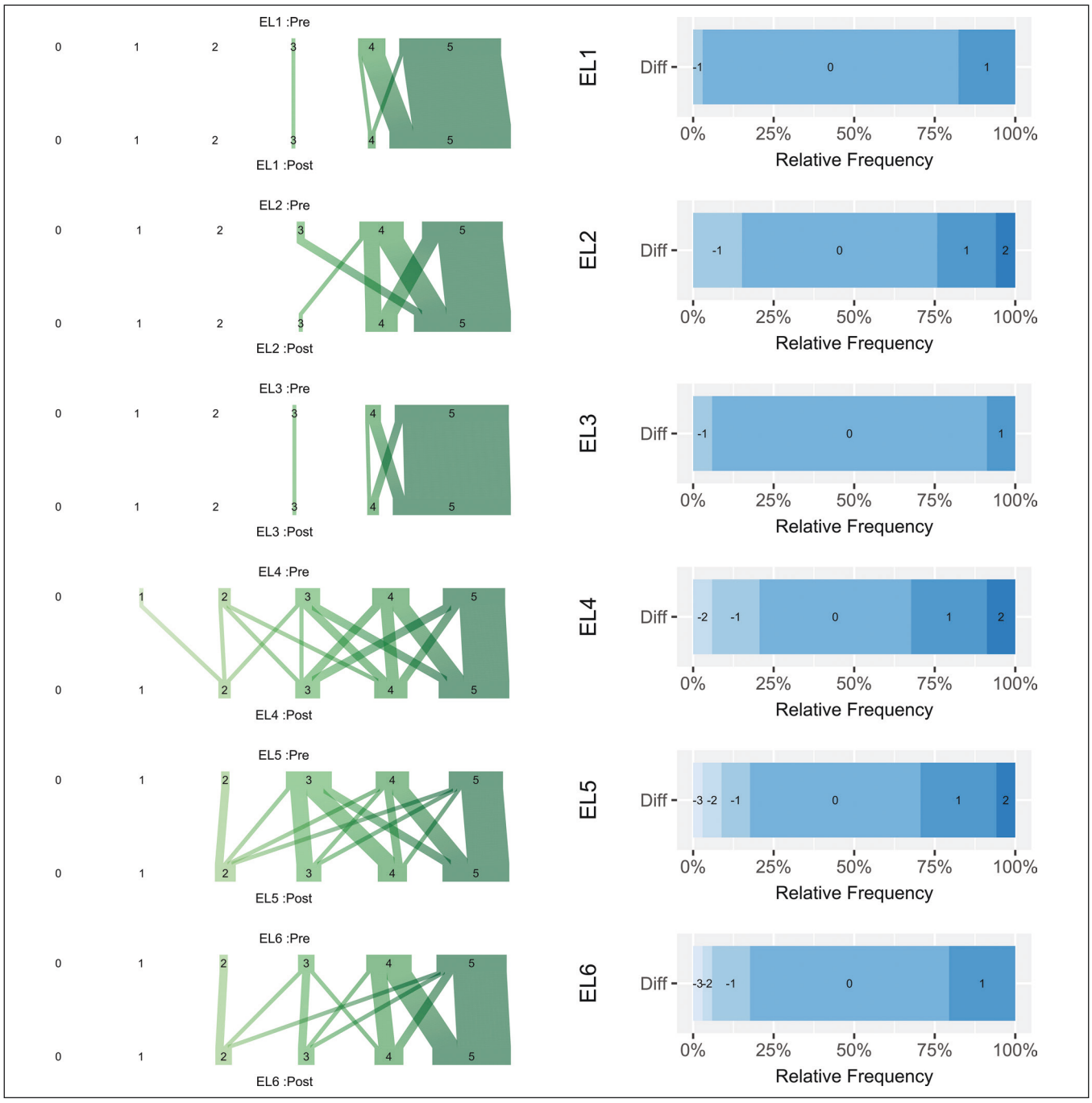
Looking at the relative frequencies of the pre–post-differences (the graphs on the right), 72% of PSTs increased 1 or more points on CSL1, indicating that nearly three-fourths of the participants felt their critical statistical literacy competence improved over the semester, and 25% of the PSTs improved their self-rating by 2 or more. Notable improvement was also seen in the responses to CSL3, with 55% of PSTs increasing their response by 1 point or more. This shows that the majority of PSTs increased their likelihood of applying their critical statistical literacy. In general, at the end of the course, the PSTs have improved expectations and value for using their critical statistical literacy both in designing educational activities for students and in their role as a teacher in an educational system.

Figure 2 shows the presurvey and postsurvey responses and changes for the survey items related to equity literacy, using the same graph types as Figure 1.

In the graphs in the left column of Figure 2, we can see that the PSTs came into their courses placing a high value

Figure 2

Responses and Changes in Responses (Diff) to Items Regarding EL



on equity (EL1–EL3) and having high expectancy for their own future classrooms regarding equity (EL4–EL6). At least 88% of responses on the presurvey were a 3, 4, or 5 for every equity literacy item. Even with such high initial ratings, there still was an increase in their value and expectancy for their future teaching regarding equity, as the percentage of five responses increased from pre to post for every equity literacy item. Looking at the bands from pre to post on EL1, we see that many more PSTs moved from 4 to 5 (six PSTs) than stayed at 4 (one PST). EL5 also showed strong increases, with six PSTs moving from 3 to 4 or 5, as well as four PSTs from 4 to 5. EL6 saw six PSTs moving from 4 to 5.

Looking at the graphs in the right-hand column of Figure 2, we see that on EL1, the vast majority of the PSTs showed no

movement. This is not surprising given the overwhelming proportion (80%) that were already at a 5 on the presurvey. We also see many more movements of +1 than of –1 on EL1. Overall, on every equity literacy question, the proportion of positive differences is larger than the proportion of negative differences. This shows that PSTs who used our materials overall tended to grow in their expectancy and value regarding enacting their equity literacy when teaching, and felt quite strongly about it.

Looking across Figures 1 and 2, it is notable that the PSTs began their semesters with generally higher expectancy and value regarding equity literacy than for critical statistical literacy. In particular, 88% of PSTs rated themselves 3 or above at the start of the semester on even the lowest-rated equity literacy question, but only 66% rated themselves 3 or above on the lowest-rated critical statistical literacy question at the start. Relatedly, positive changes from pre to post were greater for the critical statistical literacy items than for the equity literacy items.

Results for Open-Ended Items

This section presents results that emerged from the analysis of PSTs' responses to open-ended survey questions on the end-of-semester surveys. All names used are pseudonyms.

Equity and Social Justice. First, we provide results regarding all 18 responses that participating PSTs gave across all piloting courses to the query "What did you learn about equity and social justice as a result of this course?" Margaret remarked that she learned "equity is different from equality." Three of the PSTs noted they learned about issues of equity in our society at large, particularly the prevalence of inequities. An additional six PSTs' responses focused on inequity regarding a specific aspect of society: education. Most of these responses discussed factors related to inequities in education including school funding, race, poverty, and stereotypes. Regarding stereotypes, Rafael wrote, "A lot of students are disadvantaged in their ability to succeed in school due to misconceptions and stereotypes placed against them. Due to teachers expecting less of these students, they have a more difficult time being as successful as other students." All of these responses demonstrate that PSTs using our materials are improving their ability to redress biases and inequities through greater understanding about how they operate in educational settings and larger society, important for becoming equity-literate educators. Four of the responses discussed the usefulness of statistics to uncover and understand equity-related situations. For example, Maria stated, "It was helpful to learn about the misconceptions that people hold and look at the data to find out the truth and think about the real causes. . . ." Two of these four responses highlighted the utility of statistical graphs in this process. This speaks to their development of critical statistical literacy to support their equity literacy.

When asked, "What was most helpful about this course for learning ways to include equity and social justice topics in teaching?," the PSTs' responses fell into two major categories: general implications for their role as a teacher and specific implications for their teaching practice. Two responses fell into the first category; both indicated the need for teachers to address the educational inequities they learned about in this course, which signals they are motivated to respond to inequities as equity-literate teachers. The responses in the latter category gave explicit ideas concerning pedagogy that are aligned with approaches used by equity-literate educators. Two PSTs discussed implications for their interactions with students, including respecting individual differences and giving everyone the chance to speak, which are relevant to creating an equitable learning environment for students. The four additional responses concerned teaching about equity and social justice along with teaching of content and the motivating power this can have on students. To illustrate, Reuben wrote, "Including topics about equity and social justice can engage and encourage students to look into the topics that interest them and that they do have something to contribute to these ideas." Samantha remarked they learned how to hold conversations with students about equity from the course activities.

The survey also included a broader question about what PSTs learned about teaching statistics through taking the course. Many of the PSTs chose to write about teaching in ways that are tied to equity, particularly concerning creating and sustaining an equitable learning environment. Four of the students noted they learned how to teach using pedagogy that is inquiry-based and collaborative around high cognitive-demand tasks. Twelve PSTs noted the importance of an inquiry-based pedagogy where the teachers are consistently asking students questions. As Samantha said, "I learned the importance of asking questions and not just giving the answers right away. One of the most helpful things that we learned was to be aware of how the students are thinking and to ask them questions to understand and lead them in the right direction." The response of Reuben noted that they learned statistics in a way that supports development of students' conceptual understanding: "Learning the core of the statistics feels useful because I know how to explain concepts instead of just teach formulas." This speaks to the PSTs' preparedness to focus on statistical concepts as well as skills, which is important for being an equity-literate educator who employs higher order pedagogy to support an equitable learning environment (Gorski, 2013).

Critical Statistical Literacy. A final survey prompt posed two questions concerning critical statistical literacy: "What

did you learn about critical statistical literacy as a result of this course? What was most helpful about this course for learning to apply critical statistical skills?" PSTs' responses to the first question noted they learned critical statistics literacy's meaning, importance, and role in various phases of the statistical problem-solving process. Five PSTs wrote about learning its meaning, including key skills like considering lurking variables. Four PSTs noted how important critical statistical literacy is, highlighting its necessity in many fields and the need to develop it in K–12 education. Responses from 15 PSTs noted the use of critical statistical literacy in the statistical investigation process, often highlighting its application during a specific phase of the process. For instance, Tamika stated that learning how to critically interpret data visualizations is really important because the news usually presents data through graphs. Regarding the second question in the prompt, the five PSTs who responded mentioned a number of course features that were helpful for learning to apply critical statistical skills. The most common feature, mentioned by three PSTs, was group discussions during class activities. As Joseph remarked, "Having group discussions was the most helpful for this because everyone can interpret the study differently to understand it." PSTs also identified the helpfulness of examples and homework exercises for learning to apply their critical statistical literacy skills.

Discussion and Implications for Mathematics Teacher Educators

Recent position statements (e.g., NCSM & TODOS, 2016; TODOS: Mathematics for All, 2020) and teacher preparation standards (e.g., AMTE, 2017; Michigan Department of Education, 2020) emphasize prioritizing attention to equity and social justice in mathematics teachers' professional learning. However, these aspirational documents leave the specifics of how to do so to the field. This is a problem of practice that mathematics teacher educators must take on, and we chose to take on one aspect by addressing how to do so in statistics content courses embedded in mathematics teacher preparation programs. In particular, we focused on developing secondary mathematics PSTs' critical statistical literacy and equity literacy through engagement with our novel statistics teacher education curriculum materials (Casey et al., 2019).

Our results showed that PSTs who used our MODULE(S^2) statistics materials ended the semester feeling much more competent in critical statistical literacy and valued using their associated skills to support their work as equity-literate mathematics educators more. There was a synergistic effect from developing PSTs' critical statistical literacy along with their equity literacy, with their expectancy and value of both critical statistical literacy and equity literacy generally improving from the beginning to end of their courses. One enactment of this synergistic relationship in our materials is when PSTs repeatedly practice analytically examining statistical graphs and datasets in order to use data-driven arguments to advocate for equitable school practices. This couples development of critical statistical literacy skills with the ability to redress biases and inequities in the long term. As a result of using our materials, these PSTs are also likely better positioned to teach statistical lessons that address sociopolitical issues in their future classrooms.

Interestingly, as noted in the results section, PSTs entered their courses already feeling generally higher expectancy and value regarding equity literacy than for critical statistical literacy. A possible rationale we have conjectured is that our society and its associated education system results in college-age PSTs feeling more competent and placing more value on working toward an equitable educational system than applying their critical statistical literacy skills. Concurrently, in our society statistics is often portrayed as daunting, and the K–12 experiences that PSTs have often leave them feeling incompetent in statistics. Our research results showed the use of the MODULE(S^2) statistics materials meaningfully changed this, with PSTs showing strong improvement in their critical statistical literacy self-assessed rating. Additionally, PSTs who used our materials generally finished the course feeling their value and likelihood of applying their equity literacy skills when teaching was moderate to high; their intent and value to work toward providing access and advancement to every student as well as using higher order pedagogies to express high expectations for all students is encouraging. However, room for improvement still exists regarding PSTs' expectancy and value of both equity literacy and critical statistical literacy. Further study of the implementation of our materials could identify ways in which their design and use could more effectively develop these for PSTs. We also recognize that our materials are used in a single course, and our results support *SPTM*'s assumption that a focus on equity is needed throughout secondary mathematics teacher preparation programs. Additional work in this area could be grounded in secondary mathematics instructional materials that address sociopolitical issues in their statistics lessons (e.g., Berry III et al., 2020). Such efforts would familiarize PSTs with this kind of instructional material while also developing their statistical content and pedagogical knowledge. For instance, a selected lesson from such instructional materials could be used as the basis for a teaching rehearsal in a methods course. This could further PSTs' likelihood of enacting such lessons in their future classrooms.

Our work can be used in many ways by other mathematics teacher educators. One is by using our statistics materials in their courses; our materials are freely available on www.modules2.com and are accompanied by professional development materials to support mathematics teacher educators who use them. Our materials could also be useful for practicing teachers, particularly those looking to grow

in critical statistical literacy and equity literacy. The materials could be modified to use local data about sociopolitical issues and student work produced by the participating teachers' students. These modifications would make the materials more personally meaningful to the practicing teachers, potentially improving their motivation and likelihood to enact change in their teaching practice. Second, mathematics teacher educators could build on the approach we used in our materials to have a strand throughout a course that repeatedly returns to examine a systemic, equity-related topic from different angles; in our materials, this topic was income inequality in America with a focus on race. This approach allowed us to address equity at the systemic level, something Mintos et al. (2019) found lacking in secondary mathematics teacher education programs. Last, additional features of our materials that were shown to be helpful to developing equity literacy and critical statistical literacy can also be taken up by mathematics teacher educators, such as using tasks that dig into data on equity-related topics through the statistical problem-solving process, and putting emphasis on interpreting results of such tasks through courageous conversations that draw on their understandings of society and challenge their perspectives.

The research study has a few limitations to note. First, five of the piloting classes were offered during the spring 2020 semester when the COVID-19 pandemic began, so they rapidly switched to be taught virtually midway through the semester; this affected the educational experience along with the response rates to the surveys for those courses. Another is that the collected data was all self-reported by the PSTs, so the PSTs have not been objectively assessed regarding their competence in critical statistical literacy. Regarding the expectancy and value items, the PSTs' marks may be influenced by a social desirability response effect, feeling they should mark "highest importance" or "highly likely" because they perceive those responses as socially desirable.

We look to build on our present work by updating our materials to address Gorski's newer (2020) description of equity literacy educators, which gives more attention to working against oppressive ideologies and institutional cultures. It is our hope that other mathematics teacher educators can use and build on our work as well as we collectively strive to focus on equity in mathematics teacher preparation.

Acknowledgments

We are grateful to Brian Lawler and John Sutton for their assistance in designing the research study described in this article.

This article is based on work supported by the National Science Foundation (Award #1726252 to Eastern Michigan University). The content of this article does not necessarily reflect the views of the National Science Foundation.

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doi:10.5951/MTE.2021.0015

Appendix A

Selected Activities That Develop Equity Literacy and Critical Statistical Literacy

Module	Activity	Statistical topic	*SPTM* C.4 indicators
1	Reading and reflecting on gifted program admission	Choosing measurements in a multivariate environment	1,4
1	Analysis of class survey results regarding conceptions of equity	Graphing univariate categorical data	4
1	Income mobility by race, conditioned on parents' socioeconomic status	Modern data visualizations; controlling for available confounding variables; considering lurking variables	4
1	State graduation rates, separated by race and income, along with information on teacher salaries, overall funding, racial segregation, and economic segregation	Exploratory data analysis: univariate, bivariate, and multivariate, with both quantitative and categorical variables	4
1	School district funding inequalities in Pennsylvania with possible explanatory variables, including income and race	Scatterplots color-coded with additional 3rd variable (multivariate exploratory data analysis)	2,4,5
1	Air pollution in a low-income neighborhood	Design of statistical studies	1,2,3,5
1	Racial demographics of U.S. high school mathematics and science courses	Association of categorical variables	1,2,4,5
1	Travel times to school for students caught in a school-closing situation	Exploratory data analysis: Univariate and bivariate graphs; student graphical comprehension frameworks	2,3,4,5
2	Study of effects of class size on student learning	Two sample paired hypothesis test; study design	5
2	Teachers' perceptions of families' beliefs in and support of education, based on families' demographic features	One sample hypothesis test on a mean	1,3,5
2	Intervention study to address stereotype threat regarding "girls aren't as good at math as boys"	Two sample hypothesis test for means	1,2,3
3	Association of car insurance prices and racial composition by zip code	Linear regression	2
3	Reform-style teaching and student success	Linear regression, inference on slope	1,2,4,5
3	Association between percent of students who receive free lunch and average math test score in each district in a state	Differences between correlation and causation; interpretation of slope of linear model	1,4
3	Americans' opinions about the importance of education, by race and income	Categorical association: relative frequencies, segmented bar graphs and other graphs, Chi-square hypothesis test	2,3,5
3	Demographics of U.S. mathematics teachers	Categorical association: relative frequencies, interpreting tables	4,5
3	Class size inequities in Michigan	Interpreting a multivariate graph; race vs. poverty as predictor of large class sizes	4,5

Appendix B

Activity 11 Excerpt

Students' Graph Comprehension

The field of statistics education has a considerable amount of research on students' graph comprehension. *Graph comprehension* refers to the ability of a person reading a graph to determine meaning. Different levels of questioning invoke different levels of comprehension. Attributes of the student, including knowledge of context and visual decoding skills, also influence graph comprehension. In this activity, you will learn about frameworks addressing how students read statistical graphs.

Question 11-a

With your group, read the description of your assigned framework (shown below), then develop a short (approximately 5 min) presentation. Your presentation should include the framework name, its purpose, its components, and examples of its components with *your group's own new* examples.

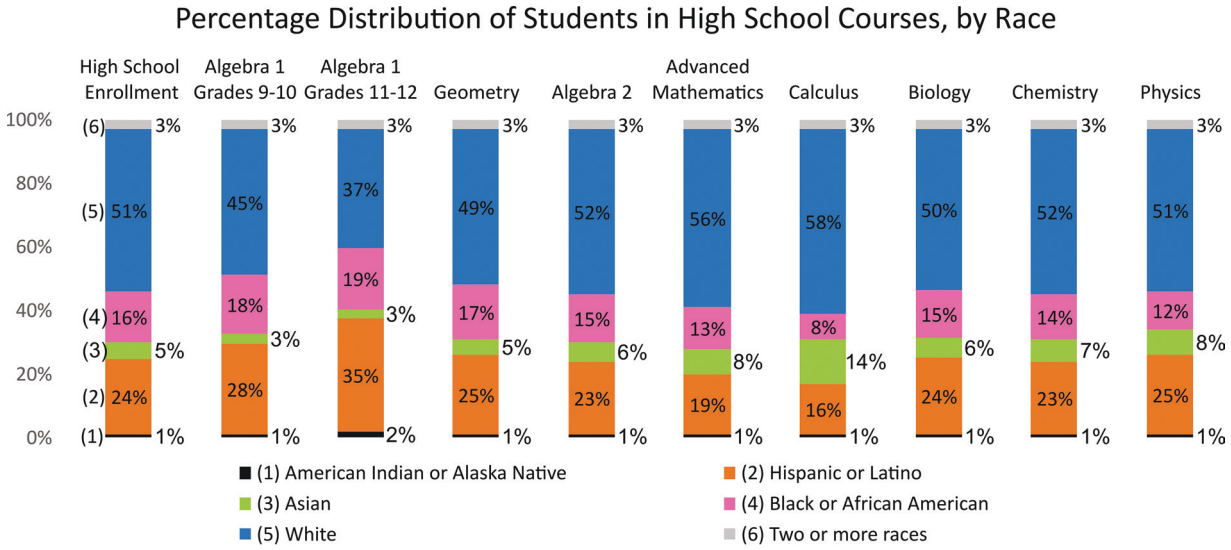
Levels of Graph Comprehension Framework

Curcio (1987) described three levels of graph comprehension that emerge from asking different types of questions about a graph. The following table describes each level and gives example questions pertinent to the previously-viewed graph from Activity 8 about perceptions of healthy food (Quealy & Sanger-Katz, 2016).

Level	Description	Example questions
Reading the data	Extracting information from the graph to answer a question for which the answer is apparent in the graph	Which food did the least percentage of nutritionists identify as healthy?
Reading between the data	Interpreting and integrating (e.g., comparing) information in the graph along with possible use of mathematical concepts and skills to answer a question	Which food had the biggest discrepancy between the percentage of nutritionists and Americans identifying it as healthy? What percentages of each group identified it as healthy?
Reading beyond the data	Extending beyond the data at hand to make predictions or inferences	Which types of foods did a greater percentage of Americans than nutritionists identify as healthy? What might explain that?

Question 11-b

The following graph, adapted from a report from the U.S. Department of Education Office for Civil Rights (2018), displays the percentage of U.S. high school students in math and science courses in 2015–16, by race, along with the racial composition of U.S. high schools in general:



Data source: US Department of Education, Office for Civil Rights, Civil Rights Data Collection, 2015-2016
Note: Data may not add up to 100 percent due to rounding.

Write then answer at least one question at each of the levels of Curcio's Framework:

i. Reading the data.

ii. Reading between the data.

iii. Reading beyond the data.

Question 11-c

Referring to your answers from the prework exercise, discuss a possible connection between educational tracking practices and the data presented above.

Appendix C

Postactivity Exercises for Activity 11

Exercise 1. Review your answers for *Question 11-b* and *Question 11-c,* and reflect on the discussion you had in class. What type of study would be most appropriate to investigate:

(a) The idea that tracking decisions are influenced by the race of the student? Write down a statistical question and a plan for sampling, treatment conditions (if applicable), and data collection.
(b) The effects of tracking on students? Write down a statistical question and a plan for sampling, treatment conditions (if applicable), and data collection.

Exercise 2. Turn back to the T-chart in Module 1 Lesson 6 (Question 6-c). Based on your thoughts from this lesson (Questions 11-b and 11-c, in particular), update your T-chart (add, cross out, or annotate items). Submit your updated T-chart in whatever form your instructor has specified.

Exercise 3. In this exercise, you will investigate whether there is evidence of race-related academic tracking at Western International High School in Michigan (one of the schools focused on in Activity 12) through analysis of data available at the Michigan School Data website. Historically, Western International High School's student body is approximately 73% Hispanic/Latinx, 18% African American, and 9% Caucasian.

Visit the Michigan School Data parent dashboard at https://www.mischooldata.org/dashboard-home/. Then search for "Western International High School" using the *Search for a School* option.

Scroll down to see what percent of students in grades 11 and 12 enrolled and passed advanced coursework in recent years. Next, use the *Student Group dropdown menu* repeatedly to disaggregate this data by race.

(a) Does there seem to be evidence of race-related academic tracking at Western? Why or why not? Sketch one or more graphs to visually display the data you have found.
(b) What other information would you need in order to do a more complete analysis of this question?
(c) Watch the student's speech at http://bit.ly/DesignEDA by selecting "Design EDA Lesson 6 Video 2." How does this add to your understanding of the metrics you collected from Western?