
Statistical Education: A Context for Critical Pedagogy

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As our society continues to become more diverse in race, culture, ethnicity, class, and sexual orientation the educational systems we have in place must also revise their purpose and their context. An important conviction of the social justice pedagogy is that teachers as well as students are a part of the solution to injustice. Teacher education programs need to equip teachers with the empathy, consideration, and the skills necessary to appreciate all the children that comprise their classroom, their school, and their community. We merged the research domains of statistics and social justice to design a teacher education course – the key goals was to develop a community enable teachers to investigate social issues with a critical eye, so that the inequities become apparent and ideas for change may be discussed.

A Rationale for Our Inquiry

The UNESCO, in its *World Declaration on Education for All* (1990) calls for “universal access” to education for all children. This declaration emphasizes that the purpose of education should be to help mankind develop “both essential learning tools, such as literacy, oral expression, numeracy and problem solving” in order to enable all citizens to “live and work in dignity, to participate fully in development, to improve the quality of their lives, to make informed decisions, and to continue learning.” There are several stakeholders that are responsible for realizing this mission in the society both at the macro and the micro levels. At a macro-level, we have national leaders who are committed to advancing these goals, policy makers who develop supporting agendas and craft proposals, and bureaucrats who act on this agenda and enact the plans. At a more micro level, we have a robust group of champions—teachers—who are in a strong position to realize the educational goals and thereby make a long-term impact in the immediate community.

Although at times unspoken, educators maintain a sphere of influence that allows them to affectively change and promote instruction. Acknowledging the authority a teacher maintains in a classroom, to create systemic change teachers must first experience personal disequilibrium in their own ideology so that they engage in all aspects of a democratic agenda. According to Skovsmose and Valero (2002), democracy:

Has the purpose of transforming the living conditions of those involved, allows people to engage in a deliberative communication process for problem-solving, and promotes collection, that is, the thinking process by means of which people, together, bend back on each other's thought and actions in a conscious way. (p. 397)

When a democratic agenda is in place, the full realization of how power is used and maintained in the larger societal picture can be recognized. Therefore when disequilibrium is supported through instruction, students, as well as educators, are stimulated to make accommodation in their belief structures through the use of differentiation, class extension, or reconceptualization (Wertsch & Polman, 2001).

Once a more inclusive view of the world in which we live is recognized, teachers become agents of change within their classroom, opening up communication so that their students experience the full benefit of a democratic education. As teacher educators, we utilized statistics as a tool to transform oppressive ideology and promote self-awareness and self-sustaining behaviors. In merging the research domains of statistics and social justice to design a course for teachers in statistics, it was our priority to establish connections to the chosen research domains and to classroom practices. Our broader research goal is to engage in a self-study (Arizona Group, 1996) to better understand how well we were able to realize this goal. In conceiving, teaching, and reflecting on this course, we were inspired by and heavily drew on what we view as overlapping research domains—statistics education and critical mathematics education. In this paper, we reflect on our personal, practical and professional knowledge experiences grounded in the context of a teacher education course aimed to promote connections to our theoretical ideologies and our practical enactments.

Theoretical Underpinings

Critical Statistics for Social Justice

Building off of the idea first introduced by Frankenstein (1990) of critical mathematics, critical statistics acknowledges the political nature of knowledge and how data can be construed and misrepresented when used in a public arena. Within the realm of statistics, because data and data analysis is not widely understood or questioned, those making the declarations based off of statistical analysis often maintain or claim the power for political stakeholders. Understanding how statistical knowledge is valued and who is making that decision helps individuals to better understand their social realities and how power struggles are enacted and sustained. Frankenstein (1995) when explaining the foundations for critical mathematics states that by asking students to think “critically by examining its underlying interests and methods of collection, description and inference, and by considering historical, philosophical, and other theoretical insights along with statistical knowledge” (p.192) build the capacity to enter into a meaningful conversation about productive change.

Critical pedagogy, the umbrella under which these ideas fall is the “attempt to be discerning and attentive to those places and practices in which social agency has been denied and produced” (Giroux, 2011, p.3). Critical pedagogy brings attention to oppression and allows individuals to become an agent of change that will promote liberatory social change over time (Frankenstein, 1987). We engage in an inquiry into our teaching practices to better understand how we can teach statistics that helps learners attain the content proficiency advocated by proponents of statistics education, but beyond that, equip them with the empathy, consideration, and the skills necessary to appreciate all the children that comprise their classroom, their school, and their community.

Skovsmose (1985) states that when implementing critical education pedagogy two criteria, subjective and objective, need to be used when selecting problems for the classroom. First the subjective requires that the problem appears relevant to the students and within their conceptual understanding. The second, the objective, requires using an existing social issue to build deeper understanding. Therefore, the

amalgamation of statistics and social justice provides a platform to have meaningful conversations about issues that impact our world and prepare individuals for active citizenship.

Statistics: Numbers with Context

In today's world, data is omnipresent and practitioners of statistics receive, consume, and interpret data in different ways. An individual awestruck by data seldom questions regarding statistics and places a blind trust in what it may convey; on the other end of this diagonal is a cynical consumer who dismisses any statistical findings and conclusions. In between the two lie the naïve consumer and the critical consumer. A naïve consumer, because of a limited and superficial understanding of data and related ideas is unable to question or critique statistical information whereas a critical consumer is able to ask questions and discern information about data, its collection and analysis methods, and conclusions that are warranted by data (GAISE, 2007; Best, 2001).

Garfield and Ben-Zvi (2008) note that in the realm of statistics, “context provides meaning for the numbers and data cannot be meaningfully analyzed without paying careful consideration to their context” (p. 8). Statistics education takes formal mathematics and provides a context that allows an individual to form questions and conclusions based on a quantified analysis. Statistics education cannot be seen as disconnected rules and ideas but, as a “powerful and relevant tool for understanding complicated, real-world phenomena” (Gutstein, 2006, pg. 30). According to the National Council of Teachers of Mathematics, statistics education must incorporate problem solving, reasoning, and communication, a method that allows mathematics to occur within the context of children's developing understanding of their world, both cognitively and socially (NCTM, 2000). In line with these recommendations, we chose activities and data sets that will enable participants realize the “proficiency goals” but also provide a heightened context for exploring the socio-political dimensions of mathematics and statistics education. We hoped that our teachers will realize that the purpose of teaching statistics is “not only to [enable students] be competitive workers in the economy but also [become] engaged participants in a democracy, able to be

critically reflective about the role statistics has played and can play in our society (Lesser, 2007, p. 3).

Contextual Setting

The course in discussion, “Probability and Statistics for high school teachers” was (re) designed to create a community of participants that can work together to negotiate a broader and deeper understanding of statistical ideas, the role of statistics in today’s society, and perceptions of the role of social justice in a mathematics classroom. The geographical setting for the course is a large mid-western university in the United States. This course is one of several content courses that we offer for in-service teachers enrolled in a Master of Arts in Teaching (MAT) program in mathematics. It is a 3-credit hour course (approximately 38 contact hours) and is usually taught during the summer term to accommodate teachers’ schedules. Over three-weeks of summer, course participants met for approximately three hours a day, five days a week. While both authors were involved in the planning of the course, the first author taught the course to a group of eleven teacher participants. The identified course goals were to help participants a) understand the statistics (and the potential it holds) to explore social justice issues and b) understand and engage in statistical thinking and thereby deepen their content and pedagogical knowledge of statistics.

We used two key resources for this course—*Rethinking Mathematics* (Gutstein & Peterson, 2013) and *Workshop Statistics: Discovery with Data* (Rossman & Chance, 2012). We also used data sets from several web-based sources including the world bank, population connection, UNICEF, WHO, and the United States Census Bureau. Activity-based learning was emphasized and course participants engaged in content, pedagogical, and curricular explorations to accomplish the course goals. The focus of the content explorations was to better understand what it means to understand and reason about statistical concepts and thereby emerge and grow as critical and caring consumers of data. Pedagogical explorations were focused on identifying methods for developing students’ understanding and reasoning about these concepts, and curricular investigations required teacher participants to identify and develop tasks that will foster a deeper and richer understanding of statistics and social justice issues.

Technological aids such as a TI-83 calculator, Fathom software, and Excel were used during content exploration sessions. Participants completed problem sets that focused on statistical concepts including sampling methods, study design, data displays, descriptive statistics, random variables, correlation, regression and probability. Real data derived from multiple sources (e.g., World Factbook, www.gap-minder.org, and world population statistics) were used to investigate many of these concepts. Concurrently, participants read and reflected on chapters from *Rethinking Mathematics* (e.g., Home Buying While Brown or Black, Sweatshop Accounting, Math, Maps, and Misrepresentation) to generate and foster critical reflection on the use of statistics to explore socially relevant issues.

Practical Enactments

The connections between statistics and social justice are complex and nuanced. Each component holds personal implications that may influence individual progress and therefore when constructing this course we had to think about the statistical content as well as the contextual issues that influence individuals. The ethical guidelines of the American Statistics Association highlight that practitioners of statistics need to realize the “social value of their work and the consequences of how well or poorly it is performed [which] includes respect for the life, liberty, dignity, and property of other people” (www.amstat.org). In our context, this highlights the need to pose questions that will lead both teachers and their students to investigate social issues with a critical eye, so that inequities become apparent and ideas for change discussed.

Addressing Barriers for Implementation

Striving to develop and implement a social justice agenda is not an easy task. Often time there is no context, nor content for a social justice agenda within a conventional mathematics classroom. Limited modes for curricular resources, professional development, or models exist to demonstrate that a social justice agenda will blend with and enhance other content disciplines. One obstacle that must be addressed

concerns a widespread belief that students are not mature enough or ready to engage in a discussion centered on sensitive social issues. Another barrier concerns the notion that when using a social justice foundation, meaningful statistics or mathematics, is absent from the curriculum. Many teachers believed that it is necessary “for students to learn the necessary math to deal with and get past the unjust gates in front them—and the math necessary to tear down the gates entirely” (Gutstein & Peterson, 2013, xii). However, during a regular school year, they are often inundated with the day-to-day routines and practical ideas of teaching, leaving little time to take on new challenges.

In the context of our research and development for this class, we, the collective whole, had to come together to address these challenges. We understood and embraced the concept that if we failed to produce meaningful dialogue, or if dialogue is absent, change cannot occur. To better cater to the needs of our community, we introduced teachers to “Rethinking Mathematics” to negotiate broader meanings for mathematics and statistics and their role in today’s society. Teachers read several chapters from the book and shared their opinions through discussions, debates, seminars, and presentations. As teachers became familiar with new resources on teaching mathematics using the lens of social justice, they too were inspired to develop activities that are relevant to their immediate context. Participation in these activities not only gave members of our community an opportunity to experience personal disequilibrium in their own ideologies but also resulted in a collection of curricular resources that could be used in mathematics classrooms. We provide two activities from our course artifacts (instructor-developed and participant-developed) that pushed us forward in addressing the challenges to our social justice agenda.

Instructor-developed artifact: World population statistics. We used world population data to discuss the potential for a critical analysis and interpretation of statistics. First, we watched a you-tube video “The world is a village” that gave a sneak preview of the world population statistics, condensed to fit a village with 100 citizens (<https://www.youtube.com/watch?v=i4639vev1Rw>). Next, we presented an activity “Food for thought” from the Population Connection web source (www.Populationconnection.org) and simulated the world population of different continents and became aware of socially relevant statistics on wealth, health, sanitation, and pollution. To uncover and understand our personally-held beliefs about the nations of and the issues facing

the world, we watched a TED talk titled “Debunking myths about the third world” and played the Gapminder sorting game (www.gapminder.org/GapminderMedia/GapPDFs/GapminderSort/GapminderSort.pdf). Next we used the Gapminder free online data visualization software (www.gapminder.org) to investigate and interpret data compiled from various international sources (e.g., UNICEF, World Bank, WHO). In particular, we focused on understanding the dynamics of the graphs and the available options for choosing scales (linear or logarithmic), indicators (e.g., life expectancy, infant mortality) and categorizations (e.g., income, religion) to generate graphical displays. We further explored the Gapminder world graph to better understand the types of statistical analysis exemplified in the dynamic illustrations.

Our preliminary analyses resulted in an investigation of several open-ended questions that could be explored using the world statistics such as: a) How do social and political changes affect literacy rates in West Africa? b) What government changes affect the health and wealth of Iran and China? and c) How have major natural disasters affected the countries of Venezuela and Bangladesh in terms of their political and economic stability as well as their overall development? We encouraged participants to propose their own questions (and possible sub-questions) that they could address by analyzing and interpreting the data using the software. A detailed report of participant-developed artifacts is available elsewhere (Poling & Naresh, 2014). We provide some examples of teacher-generated Gapminder questions here. a) How did the Vietnam War affect life expectancy in the countries involved in the war? b) Look at the Life Expectancy Graphs over time for Vietnam, Cambodia, China, Taiwan and the United States from 1940 to 2012. Describe any trends that you notice, and c) How does the expenditure per student at the primary level affect math achievement in the 8th grade? Compare the following countries: United States and Japan.

Engaging in this activity was an eye-opening experience – as we engaged in an analysis of data about the world nations including the so-called third world nations, we realized that many of our personally-held views turned out to be myths that were thwarted by a critical and careful analyses of data. We are now more attuned to our personal beliefs and their potential impact on our roles as educators in the society.

Teacher-developed artifact: World population statistics. All teacher participants completed a course project that required them to

develop a statistical lesson that could be taught to students in grades 7-12. Teachers were encouraged to connect statistical concepts to understand relations of power, resources inequities and disparate opportunities between different social groups. The following sub tasks were assigned.

1. Reflect on the course readings and propose a definition of social justice that makes the most sense.
2. Identify potential data sources that relate to your social justice theme. Identify sources of data that are most useful in exploring key statistical concepts.
3. Identify at least three key statistical concepts that are central to the lesson.
4. Develop a class activity/task. Include procedures for implementing the activity. Discuss one or more approaches to solving the problem.
5. Describe why the chosen activity is appropriate for the chosen grade level.
6. What connections to other mathematical topics / subjects could be made?
7. Establish specific connections to the GAISE guidelines and the CCSS-M standards.

At the end of the first week of classes, teachers completed a course project outline that included responses to the first three tasks. After receiving feedback from their instructor, they incorporated suggested changes (if any) and developed the intended activity. During the last day of classes, they enacted their activity with their peers. Examples of teacher-developed activities include *Pay inequity in the workplaces*, *Racial disparities and graduation rates*, *Racial and wealth divide*, *Disproportionate distribution of a city budget*, and *A comparison of two school districts budget allocations*. Here is an example of a teacher-developed activity. The teacher chose to remain anonymous but graciously gave us permission to use this artefact.

Title: Racial Disparities and Graduation Rates.

1. Definition of Social Justice: Social Justice is the view that all individuals deserve equal rights, opportunities, and economic growth. Social Justice is a process which seeks fair treatment

and opportunities, challenges prejudice, empowers people to take a stand, and builds more understanding in our worlds.

2. Data Sources
 - a. http://www.edweek.org/media/ew/dc/2006/oh_SGB06.pdf – HS Graduation Rate
 - b. <http://www.radicalmath.org/docs/EducationPayso5.pdf> – Benefits for Higher Education
 - c. http://collegecompletion.chronicle.com/state/#state=oh§or=public_four – College Completion Rates
 - d. <http://www.fastweb.com/financial-aid/articles/3930-shocking-student-debt-statistics> – Student Loan Debt
 - e. http://www.bls.gov/emp/ep_chart_001.htm – Earnings and Employment Rates by College Graduate
 - f. <http://www.all4ed.org/files/Ohio.pdf> – Ohio Dropouts affecting economy
 - g. <http://www.dispatch.com/content/stories/local/2012/11/28/ohios-grad-rates-show-racial-disparity.html>
 - h. <http://www2.ed.gov/about/pubs/publications-reports.html> – Department of Education
3. Key statistical concepts:
 - a. Represent data with plots on the real number line (dot plots, histograms, and box plots).
 - b. Use statistics appropriate to the shape of the data distribution to compare center and spread of two or more different data sets.
 - c. Recognize possible associations and trends in the data.
 - d. Distinguish between correlation and causation.
4. – 7) Due to page limitations, we are unable to provide the entire activity in this paper. We will include a comprehensive overview of the lesson in our presentation. Here, we list a set of questions that were central to this discussion.
 - a. Describe how you can use data to decide if there a racial gap between the overall black and white graduation rates.
 - b. Describe how you can use data to decide if there a racial gap between black and white graduation rates.
 - c. How does Ohio compare with the other states? Did Ohio fail at all levels (black, white, overall) with the graduation rate?
 - d. What could we do to improve the gap?

Through such activities, we were able to emphasize the significance of engaging in an iterative process of data collection, exploration, analyses, and interpretation (GAISE, 2007) to promote statistical literacy and empower individuals “to use statistics to “talk back” to or change the world” (Lesser, 2007, p.2).

Keeping the Conversation Alive

As our society continues to become more diverse in race, culture, ethnicity, class, and sexual orientation the educational systems we have in place must also revise their purpose and their context. As articulated in Program Ethnomathematics (D’Ambrosio, 2007), a curriculum for critical pedagogy must encompass three strands—*literacy*, *matheracy*, and *technoracy*. Literacy is the ability to absorb and process information and could include numeracy, matheracy goes beyond numeracy and enhances an individual’s ability to absorb information, develop a hypothesis and draw relevant conclusions, and technocracy equips an individual with the skills necessary to understand the potential that it holds to benefit or destroy mankind. Although we did not set out our course aligned to the key tenets of Program ethnomathematics, in hindsight we realize that, as a community of learners, we have grasped and appropriated many of these principles during this course. We truly believe that our teachers have a much deeper understanding of the role of statistics in today’s society and have grown as critical and caring consumers of data. As members of a community that aimed to foster critical statistics pedagogy, they are not only able to think and reason about statistics but also are able to use statistical tools to better explore and understand issues that are significant to their immediate community, the larger society, and the broader world.

It is extremely important to view learners as “democratic citizens” to increase their “awareness of social justice issues” (Lesser, 2007, p. 3). In such a democratic setting, terms and definitions, including that of social justice are subject to multiple connotations. As staunch believers of a critical mathematics pedagogy, we, at times, were inclined to question teacher-proposed definitions and interpretations of social justice and their attempts at translating these constructs into their classroom teaching. However, we have come to realize that it is simply unjust to impose our interpretations suppressing those of the

others. Instead, we use the voice and the views of the others' to create instances of cognitive dissonance and use such instances to negotiate and (re) conceive newer meanings for teaching mathematics. It is imperative that we equip teachers with the empathy, consideration, and the skills necessary to appreciate all the children in their classroom, their school, and their community. We need to achieve this by making a genuine attempt in facilitating an inclusive environment to engage others who do not already share our ideologies and visions for realizing the educational goals. Teaching statistics for social justice focuses on the use of statistics as a means to see many different interpretations of the same phenomenon, not only the dominant view. Using Gutstein's (2006) work as an impetus for this trajectory, statistics education "for social justice flows from the broader notion of liberatory education and has two sets of pedagogical goals: one focused on social justice and the other on" statistics (p. 23).

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