Equitable Mathematics Instruction: Lessons from the Matherscize Girls' Summer Camp

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Abstract

Implementing equitable strategies in whole-class instruction continues to be a challenge for teachers in multicultural settings. This study investigates three teachers' reform-based instruction in Matherscize, a mathematics summer camp for middle school girls. Participants were most challenged when incorporating contextual elements into their teaching; content and pedagogical goals were less challenging. Besides curricular aspects and implementation of lessons, teachers' perspectives about mathematics teaching and learning also impacted equity pedagogy. Characteristics particular to teachers' practice emerged - collaborative knowledge production, student authority and ownership of knowledge, and mutual respect, suggesting teachers' attention to incorporating social justice values into their teaching. The study suggests that future research needs to focus on understanding how social justice values play out in equitable mathematics classrooms.

Key words: Equity pedagogy, learner-responsive pedagogy, social justice

1. Purpose of the Study

The National Council of Teachers of Mathematics' (2000) Equity Standards in the United States promotes a vision of mathematics education that supports *all* students through "reform" mathematics; the document emphasizes students engaging in mathematical ideas through explorations and real-world problems. Student written and oral communication, work in collaborative groups, making connections between concepts, and using multiple representations are suggested as strategies to make mathematics more accessible to learners in a multicultural context. Additionally, research affirms that by using collaborative work, real life applications, and current event analysis, teachers can make instruction more equitable for all learners (Gutierrez, 2002; Gutstein, 2005). However, explorations with reform-based methods have shown that teachers face challenges as they negotiate issues within the larger context of the school and community, as Lubeinski (2002) described for students of low and high socio-economic status (SES). Teachers also enter their classrooms with their own perspectives on mathematics content and pedagogy (Erchick, Dornoo, Joseph, & Brosnan, 2010), each of which influences their instructional and pedagogical choices. While teachers' mathematics content perspectives range from purely conceptual or procedural to an integrated conceptual-procedural view, pedagogical perspectives range from a teacher-directed to a learner-responsive approach (Erchick, Dornoo, & Joseph, 2011).

This study investigates curricular and pedagogical elements of three teachers using reform-based instructional approaches in an informal setting. The particular setting of the camp was chosen for the study because it provided a rich environment for pedagogical explorations. In particular, the study seeks to investigate: (1) ways in which teachers' instructional decisions support curriculum for equitable teaching, (2) "particular" (Boaler, 2002) equitable classroom practices that teachers find least and most challenging, (3) ways in which teacher perspectives influence their pedagogy.

2. Literature Review

Multicultural education theorists like James A. Banks, Marilyn Cochran-Smith, and Gloria Ladson-Billings agree upon some key features of teaching for equity:

1) recognizing that racism exists at individual, institutional, and cultural levels,
2) that racism is perpetuated in educational settings, both in curriculum and practice,
3) that the purpose of education must go beyond content knowledge and passing standardized tests, and
4) that building students' critical consciousness must be an expected outcome of education.

Paulo Freire uses the analogy of "reading the word and the world" (Freire, 1993). What does this mean for pedagogy and instruction? Banks and Banks (1995) describe equity pedagogy as teaching that is dynamic, by virtue of being strongly student-centered and flexible in being able to cater to individual student needs. Ladson-Billings (1995) posits a *culturally relevant pedagogy*: "specifically committed to collective, not merely individual, empowerment" (p. 160); a pedagogy that places high expectations on all students, and helps them achieve academic excellence, cultural competence and critical consciousness.

Therefore, equity in mathematics education not only caters to a diverse range of student ability and understanding, but also provides opportunity to promote the ability to challenge inequities in society through mathematics (Gutierrez, 2002; Gutstein, 2006). In doing so, the objective is to provide students an opportunity to engage with the content of mathematics by making it accessible to all students, but also to prepare informed citizens. Consequently, equity pedagogy emphasizes discourse in 'learning communities' (Manouchehri, 2006) in which children feel safe to ask questions, express views and exchange ideas. It necessitates teachers' familiarity with real-world contexts (Ball, 2000), and facilitate bringing the world into the classroom (Gutstein, 2006).
In particular, three dimensions of a teacher's pedagogy are considered critical to equitable mathematics classrooms:

a) a clear focus on mathematics content (Ladson-Billings, 2005) - Teaching for equity necessarily places a high priority on mathematical competency; students need to be competent in mathematics, which provides a "gateway"(Bryk & Treisman, 2010) to a variety of careers in the present-day technology-driven world. Attention to mathematics content includes:

- focusing on the meaning and use of mathematical language,
- focusing on mathematical reasoning
- focusing on mathematical practices

b) learner-responsive pedagogy (Erchick et al., 2011; Boaler, 2002, Esmonde, 2009) - The second dimension of teaching for equity is pedagogical and includes:

- explicitly communicating reasoning, tasks, and ideas,
- spending quality time on engaging mathematics
- collaboration to include a diversity of competencies
- providing autonomous work opportunities for students,

c) application of real-world contexts (Boaler, 2002; Banks, 1995; Gutstein, 2006) - Achieving equity must consider the lived experiences of students outside the classroom by:

- making real world contexts accessible through mathematics,
- providing all students with the opportunity to understand the world critically through high expectations of all learners,
- and focusing on student effort and self-empowerment with the goal of becoming agents of social change (Banks, 1995; Gutstein, 2006).

While research investigating reform-based teaching practices reports some exemplary vignettes, studies in various contexts are needed to inform "theoretical understanding of the issues as well as [our] practical efforts to reduce existing disparities" (Gutstein, 2005 p.95). Research on teaching mathematics for equity has been critiqued for its ambiguity, its lack of focus on mathematics content, and too much emphasis on non-educational goals (Cochran-Smith, Barnatt, Lahann, Shakman, & Terrell, 2009). Hence, this study particularly investigated teacher practice in three areas – content objectives, pedagogical orientation, and contextual relevance. The purpose of this study was to help make teaching for equity accessible to teachers and teacher educators, drawing from the experience of three mathematics teachers' equity pedagogy.

3. The Study

3.1 Context

The context for the study was Matherscize, a mathematics summer camp for girls in the middle grades (grades 5-7). The camp enrolled nineteen students from diverse environments and across all three of the targeted grade levels. The camp was held for five days, from 9 a.m. to 3 p.m. each day, with a 45-minute lunch, and covered five strands of middle grades mathematics: number and operations, algebra, geometry, measurement, and data analysis and probability. Process standards for school mathematics, as outlined in the Principals and Standards document (NCTM, 2000) were emphasized in the pedagogy: problem solving, reasoning and proof, communication, connections, and representation. The camp setting was selected as a research site for several reasons: it eliminates variables that might prove challenging to equity, such as the school's administrative control, teaching to the test, and completion of concepts within a fixed period of time. Moreover, the setting provides teachers the flexibility to explore with a variety of instructional and pedagogical strategies.

3.2 Participants

Participants for the study were three consenting teachers, Mark, Megan, and Rachael (all names are pseudonyms), chosen through a purposeful selection process. The participants covered a range of experience and place in their career trajectories; Mark is an Assistant professor of Mathematics Education with two years of teaching at the college level, Megan is a recent Ph. D. graduate with two years teaching at the camp and beginning a career as an assistant professor of Mathematics Education, and Rachael is a recent graduate of the institution's teacher licensure program and beginning her career teaching middle grades mathematics. In addition to university experience, Mark and Megan also have experience teaching high school mathematics. All three participants consented to participate in this research.

3.3 Data sources

Curriculum used at the camp, and video-recordings of sessions kept as a reflective tool for the program formed the data sources for the study. These were used with the permission of the participants. Curriculum for the camp comprised twenty teaching sessions over five days, covering five units of middle grades mathematics. Participating teachers taught three of the lessons. The details of the sessions of participating teachers are given in Table1 below:

Session	Mathematics Content	Mathematics Processing	Purpose	Methodology	Sessions/# of hours of video recording
Swamp Angel (Issacs, A. (1994). *Swamp Angel*. New York: Sutton Children's Books).	Representation and interpretation of statistical data, Units of measurement	Multiple representations, Communication, Connections across content areas.	Select and use statistical methods. Create and use representations to organize, record and communicate mathematical ideas coherently to peers, teachers, and others.	Process Drama[1], students work in small groups to argue and defend a legend by examining statistical information	Two 45-min. sessions and 1 hr. 17 min. of video recording.
Tangrams	Triangles, squares, rectangles, parallelograms, trapezoids.	Visualization, Communication, Connections across content areas	Use tangrams to understand properties of geometric figures, explain and justify conjectures.	Students work in small groups to represent and manipulate geometric shapes.	One 45-min. session and 17.07 minutes of video (rest of the time was spent on group work)
Taxi geometry (Borasi, 1992): The role of definitions in geometry	Circle: definition and comparison between Euclidean and taxicab geometry	Visualization, Mathematical language, Communication, Argument	Discuss and agree on a definition and defend the definition in Euclidean and taxicab geometry. Learning to argue in mathematics, and think outside the box.	Whole-class discussion to generate the definition of a circle and argue the case for or against the definition in taxicab and Euclidean geometry	Two 45-min. sessions and 1 hr. 30 min. of video recording.

Table 1: Participating Teachers' Session Details

3.4 Data Analysis

Lesson plans and transcriptions of three hours of video-recordings of the sessions were analyzed. The coding used a variation of the "Use of mathematics to teach equitably" (Table 2) codebook (Erchick et al., 2010). The codebook is grounded in literature generated from the work of various researchers (eg. Boaler, 2002; Delpit, 1993; Erchick, 2002; Ladson-Billings, 1995) and contains features covering a range of practices in an equitable mathematics classroom. Codes are categorized under three main headings: content objectives (teacher's attention to mathematics), pedagogical orientation (purposeful support of students as learners), and contextual relevance (awareness of instructional context). Table 2: Modified codebook is from "Use of mathematics to teach equitably"(Erchick et al., 2010). In practice, there are twenty codes, with each code having E for Example, and N for non-example attached to it.

[1] Process Drama, a field in literacy, was the methodology for this lesson.

Category I – Content objectives (Att **ention to mathematics)**
ETL: Explicit Talk about the meaning and use of mathematical Language **Teacher explicitly pays attention to language or notation used. The teacher defines terms, emphasizes the meanings, shows how to use them, and specifies the labels and names used in mathematics. Warrant: Ladson-Billings, 1995; Delpit, 1993.**
ETR: Explicit Talk about ways of Reasoning **The teacher helps students to reason mathematically, by prodding or asking good questions that further student exploration and reasoning, and provides students opportunities to reason and engage with rigorous mathematics content. Warrant: Ladson-Billings, 1995; Delpit, 1993.**
ETMP: Explicit Talk about Mathematical Practices **The teacher explicitly uses mathematical practices in her teaching, such as how to use representations, how to hypothesize, how to use a definition, test a proposition, or respond to an argument. Warrant: Ladson-Billings, 1995; Delpit, 1993.**
Category II – Pedagogical Orientation (Purposeful support of students as learners)
EST: Explicit Student Tasks and work **Teacher gives students clear instructions about what tasks are expected and the work that is expected of them. The activity might involve listening, demonstrating, working on an activity, or solving a mathematics problem. Making teacher expectations clear in the classroom is one aspect of pedagogy that is culturally relevant and student focused (Ladson-Billings, 1995, Delpit, 1993). If the teacher's instructions are confusing or misleading, the code will be marked ESTN, otherwise, ESTE.**
IT: Quality of Instructional Time spent on mathematics **The teacher spends time on mathematics, or a mathematical task rather than on disciplinary, organizational, or matters irrelevant to the content. Warrant: Ladson-Billings' advice to look at how efficiently the teacher uses instructional time.**
EDC: Encouragement of a Diverse array of mathematical Competencies **The teacher supports a wide range of mathematical skill and ability. Teacher invites the participation from students with diverse understanding and supports student interactions involving a variety of competencies. The diverse mathematics may be in terms of how problems might be approached and solved as well as representational views, reasoning, precision and use of mathematical language, and questioning. Mathematical work is rigorous and diverse and student interactions support that array of mathematical reasoning.** **Warrant: According to Boaler (2002), teachers who create a classroom environment in which all students' ideas are accepted and encouraged provide a space for all students to learn and be successful at mathematics. Issues of inequities in mathematics instruction are mediated as students are allowed to share their views and representations. This code also draws from culturally responsive and caring theories (Ladson-Billings, 1995; Parsons, 2005) that argue for equitable teaching practices to include diverse ways for students to participate in the mathematics classroom.**
AU: Autonomous student work opportunities **Teacher encourages and gives opportunities for students to work autonomously. Teacher allows students to make decisions about how to go about doing the mathematical work. The teacher might set up a problem, provide any needed support, but allow students to solve the problem on their own, either individually through self-evaluation, or in collaborative groups. Individual work involving students practice a skill is not considered for this code.**
Category III - Contextual Relevance (Awareness of instructional context)
RWP: Real-World Problems or examples **Code for whether real-world contexts and examples were used and if they were relevant to students' experiences. This is based on research that says that when problems are drawn from students' experiences outside the classroom, mathematics becomes more accessible for students' learning (Burton, 1998; Gutstein, 2006). When contexts that are unfamiliar to some students are used, it tends to exclude them from the experience of learning the subject. For example, an activity to design one's own bedroom might be a sensitive topic for children sharing their rooms with other members of the family. Some games played in certain cultural groups might be unfamiliar to those of another cultural group. If the teacher uses a real world context appropriately in the mathematics lesson, it is coded RWPE, while it is coded RWPN if used superficially or inappropriately.**
ESE: Emphasis of Student Effort and message that effort will eventually pay off **Teacher verbally emphasizes student effort and conveys message that effort will eventually pay off. Teacher may praise student effort or encourage students to keep trying.**
EE: Expressed Expectation that everyone will be able to do the work **The teacher conveys belief that mathematics or the mathematics task at hand is something everyone can do. Examples may include encouraging students to share their ideas, recognizing a student's idea or solution by giving them opportunity to share with the rest of the class, giving opportunity for students to add or comment on mathematical work. Warrant: Culturally relevant pedagogy values having high expectations for all students (Ladson-Billings, 1995).**

Video-recordings of participants' instruction were viewed and coded to determine if a wide range of equity pedagogy were evidenced. Coding of the videos was done in lesson segments; the videos were viewed and transcribed, and then divided up into segments according to a portion of the lesson or activity that was complete either as an activity or as a theme for discussion in the class. To ensure reliability of the coding, an outside coder was asked to code a sample of the data. There was over 80% agreement between the researcher and the external coder. An example of the coding is given below.

Rachel's lesson on data analysis and representation involved a Process Drama lesson that used statistical methods to argue and defend the existence of a legendary character, Angelica. A section of the lesson transcript is given below:

Rachel: What can we do to convince them we are not lying? ..... If we can't convince them, we have to look at the data. Let's all look at the data. So we're trying to tax ourselves…. You're the best and the brightest….we need to protect Angelica too. So let's look at this data. Let's see if there's anything we can work with. Look and see if there's any [sic] discrepancies. Let's just talk about what we see. Take a minute and look…. Talk about the data in your groups and the person who has the paper, write down what each one says.

The above paragraph was coded ETMPE, ETRE, ESTE, AUE, EEE, RWPE, and ITE (refer to Table 2 for explanation). This is because using data to problem-solve is a mathematical practice (ETMPE), and students are asked to reason (ETRE), and work autonomously (AUE) to find a solution to a real-world problem (RWPE). Further, the teacher expresses expectation that the students are capable of doing the work (EEE) and students are given clear directions about their tasks (ESTE). The episode is an example of quality instructional time spent on mathematics (ITE).

3.4.1 Consolidated code-counts from session videos

Total numbers of equity codes per segment, per session, per category for each of the participants are given in the Table 3 below.

Participant	No. of session segments	Instances of Equity Codes											Codes per segment
		Category I (Content objectives)			Category II (Reform-oriented pedagogy)				Category III (Contextual relevance)				
		ETLE	ETRE	ETMPE	ESTE	ITE	EDCE	AUE	RWPE	ESEE	EEE	Total	
Rachael	6	3	5	5	5	5	4	4	4	1	4	40	6.66
		Sub-total in Category I: 13 (32.5%)			Sub-total in Category II: 23 (57.5%)				Sub-total in Category III: 9 (22.5%)				
Megan	14	12	13	9	10	10	11	14	3	7	11	100	7.14
		Sub-total in Category I: 34 (34%)			Sub-total in Category II: 45 (45%)				Sub-total in Category III: 21 (21%)				
Mark	10	7	7	6	9	7	6	10	1	3	8	58	5.8
		Sub-total in Category I: 20 (34.9%)			Sub-total in Category II: 23 (39.7%)				Sub-total in Category III: 12 (20.7%)				

Table 3: Overall Instances Of Equity Pedagogy Codes For Teacher Participants

4. Key Findings

Three key findings emerged from studying the curriculum and analyzing the video-transcripts. Even though clearly defined objectives and curricular decisions facilitated equity pedagogy, teachers' implementation made the lesson richer and more accessible to all students. Secondly, content and pedagogical objectives of equity pedagogy were evidenced more frequently in teachers' practice than equity's contextual elements. Thirdly, teacher experience and perspectives could be indicators of the extent to which a teacher might push an equity agenda. Discussion of each of these findings follows.

4.1 Teacher implementation: supporting curricular decisions

Curricular decisions were crucial to equity pedagogy: choice of activities, explorations with real-world problems, and physical arrangement of the classroom. However, teachers' implementation was influential in providing a more equitable learning environment.

From Table 3, Megan's session seemed to have generated more equity codes than those of the other participants. Considering the curriculum, it was observed that the purpose of the session included 'learning to argue', which naturally generated more dialogue among students and teacher. On the other hand, the other sessions, more focused on content had students working in small groups. Although there was discussion among these groups, this was not captured since the study focused largely on whole-class interaction.

Classroom organization also played an important role in equity pedagogy. In all the sessions, students sat around tables in small groups facing each other, facilitating collaboration. In one particular session in which students had to discuss and generate the definition of a circle, they sat around the teacher on a carpet on the floor, with the teacher noting their inputs on a board. The friendly and relaxed atmosphere allowed students to express their thoughts more openly than one might expect in a traditional classroom where direct instruction and silence are norms.

Besides curriculum and classroom organization facilitating equity pedagogy, teachers' implementation also played a major role. For example, Megan took a taxi-ride activity and personalized it:

Megan: So when you arrive by a taxi they charge you by the distance, right? So if you were riding in a taxi and they came to pick you up at the airport and they were going to take you to your grandmother's house or somewhere and if that taxi left the airport and started driving all around the airport like a couple of times, how would you feel about that?

This resulted in the students engaging with the problem, and seeking to understand the mathematical context in order to argue their point of view with better clarity.

While curricular decisions impacted the learning environment in a classroom, the teachers' ability to make lessons more student-centered was evidenced as in the above example. Equity pedagogy is therefore, not merely about using real-world activities, but taking the planned activity further to more fully engage the student.

4.2 Equity pedagogy's contextual elements: challenging for these teachers.

Pedagogical objectives of equity based on reform-based practices seemed to come more easily to teacher participants than equity's contextual elements that engage students in making real-world connections. This is evident from the percentages of counts reflected in categories I, II & III in Table 3. It is possible that the camp set up was partly responsible for teachers being able to use reform-practices in their teaching. But this finding suggests that making real-world connections, emphasizing student effort and having high expectations are challenging for teachers. Within the contextual elements, however, using real-world problems and examples (RWPE) appeared most frequently in Rachael's data analysis session and not as much in the other two. This is an expected result, since the activity was one in which students used data to solve a real-world problem. Therefore, designing lesson plans and building activities around real life situations would enhance the contextual elements of equity (Gutstein, 2005).

Secondly, the frequency with which codes for autonomous work opportunities (AUE) and expressing high expectation of everyone (EEE) appear in the data differs between Rachael and the other two participants. While Rachael is a beginning teacher, the other two are more experienced.

Providing autonomous work opportunities to students (AUE) requires teachers to forfeit their own authority, and beginning teachers might have difficulty in doing so.

Also, having high expectations of all students is a perspective of someone rooted in a social justice cause, and a beginning teacher, still in the process of learning to deal with issues like classroom management might not necessarily be in that place.

The biggest challenges in implementing equity pedagogy seem to be these teacher's ability to make connections to the students' lives and make explicit 1) that student effort will pay off, and 2) that the teacher has high expectations of all students. The latter might have been as a result of the context in which students were not required to take a test at the end of the teaching period. Teachers wanted the students to enjoy their experience at the camp and perhaps did not insist on effort as much as they might have in a school setting.

4.3 Teachers' particular perspectives: beliefs influencing equity pedagogy.

Teacher participants' particular perspectives and beliefs impacted their pedagogy. Megan, Mark, and Rachel shared equity perspectives about teaching and learning, but had distinct understandings of what mathematics is and how mathematics is done. These beliefs surfaced throughout their session, and seemed to underlie their work. Megan's perspective that students should be provided an opportunity to collaboratively generate mathematical knowledge was evidenced in discussions in her class.

Megan: Let's think about this. We are going to compare (oval and circle) with respect to the radius and diameter.
Student: A circle can be an oval; an oval can't be a circle. A circle would have more qualities; an oval has less qualities. A circle has all the oval's qualities and a oval does not have all the circle's qualities…. A circle is like a square but with rounded corners and an oval is like a rectangle with rounded corners. It's like the same thing and they compare to each other.

Megan: In that situation and that's sort of a profound statement I think.

Mark's lesson used tangrams for explorations of geometric figures. He not only provided opportunities for students to work autonomously, but also allowed shared authority and ownership of their knowledge repeatedly. The following sentences (line numbers from the transcript are included) show his repeated reference to this idea:
Mark:(*line 49*) Did you get the square? No? (*to her neighbor*) Can you show her how to get it?....(*lines 53-54*): Did you get the square? (*to another student*) Show her how to get it…..(*lines 57-60*): Is that a square?
Student: No.
Mark: No?(*to her neighbor*) Show her how to get it. Ask her.
Rachael's repeated insistence on respecting one another showed her personal conviction that recognizing and respecting what everyone brings to the table is important to equity pedagogy.

Rachael: .... from tall tales you can learn about a culture's beliefs, their values. (*lines 50, 54*): Let's be respectful, eyes on them and we would listen quietly…(*lines 56-57*): Let's listen to the Triangles. We're going to wait till everybody is quiet, let's be respectful….. (*line 59*): Let's hear what the pentagons have to say….. (*lines 66-69*): Unfortunately, those that are not familiar with the culture and values or beliefs may disrespect a tall tale or that culture. Unfortunately, since they don't understand, they may put them down. So that's why we are here today.
Each participant brought a different perspective to their instruction, uniquely influencing the lesson. The particular perspectives that were underlying the instruction in this study could not be 'coded,' but seem to point to a potential area of work that envelops equity pedagogy with social justice values of student authority, power, and respect.

5. Discussion

Equitable mathematics instruction is enhanced by clearly defined curricular objectives as well as by how teachers implement them. In their implementation of equity pedagogy, participant teachers found aligning instruction to real-life contexts most challenging. Throughout the instruction, themes emerged that were rooted in teachers' perspectives were observed: collaborative knowledge production, student authority and ownership of knowledge, and mutual respect. Hence, the author suggests that these elements, foundational to teaching for social justice move equity pedagogy to include attention to social justice values. More importantly, it is worthwhile to note that elements like student authority, and mutual respect can be made explicit in a mathematics classroom. Teaching for social justice seeks to use mathematics to build student agency, empowering students with mathematics and helping them believe in themselves (Gutstein, 2003). Although social justice literature specifically highlights these aspects of equity, this study provides a vision for mathematics teachers to make them explicit in their classrooms and for teacher educators to pay attention to particular characteristics in their work for equity.

The study is limited in not considering non-verbal communication of the teacher, which might be crucial in a multicultural and multilingual setting. This aspect of a teacher's work might be useful to consider in making classrooms more equitable for students from cultures in which non-verbal communication is critically important.

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