Equity in Problem-Based Learning
A Guide for Teachers of Mathematics

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Abstract: Achieving equitable outcomes in mathematics instruction is a lofty but elusive goal, as evidenced by standardized test results and representation in high-level courses. The role of teacher bias in choice of instructional materials and implementation requires strategic examination and corrective action in order for an individual teacher to begin pursuing equity in the classroom. Problem-based curriculum is a step towards using high-quality instruction to ensure that all students have access to challenging mathematics and the support they need to succeed. A closer look at a teacher's implementation of such curriculum illuminates the teacher practices needed to promote equity within the framework of a problem-based instructional model.

Introduction

Equity in mathematics instruction is dependent upon teacher beliefs and biases, which influence curriculum choices, instructional models, and expectations about who can learn mathematics. Problem-based learning is a reform model of teaching mathematics; in this kind of classroom, students "do math and talk about it," a shift from the traditional model of mathematics instruction demarcated by students doing more of the talking than their teacher. As equity-minded teachers implement this model, attention must be paid to which students are doing most of the talking, and whether the curriculum is engaging all students, particularly those students belonging to groups that typically lag in achievement. Mathematics classrooms characterized by problem-based learning and discussion can powerfully promote equity through carefully considered teacher practices.

Understanding Bias

Teachers, like all members of the human race, have unconscious biases, which can be thought of as unproductive beliefs based on faulty assumptions or stereotypes. Teachers are also, generally, well-intentioned individuals who are dedicated to ensuring that all students entrusted to them learn and grow. These good intentions can make teachers reluctant to admit to unproductive beliefs about some students, but it must be understood that bias is a universal condition that, left unexamined, will ultimately undermine teachers' ability to be effective. Instead of investing effort in defensiveness about intentions, teachers focused on equally educating all students must be willing to counter their unproductive beliefs.

Equal education for all students has long been a struggle for American public schools across all subjects, including mathematics. The National Assessment of Educational Progress (NAEP) test, administered from 1969 onward, has made it impossible to ignore the persistent gaps in achievement between groups of American students. A great deal of effort has been made to "close the gap," and while the

performance of all students trends upward, the gaps persist, as shown in Figure 1. Achievement gaps in math exist between students who are White and those who are Black or Hispanic; between English speakers and English-language learners (ELLs); and between high- and low-income students, as indicated by qualifying for the National School Lunch Program. Many students belong to an intersection of these groups; it is this kind of student who is most in need of high expectations from teachers who believe deeply in the ability of all students to succeed. Notably, the gap for each group has consistently widened from 4th to 8th grade, indicating that the middle grades of math instruction are vital for cultivating equitable practices (NRC, 2017).
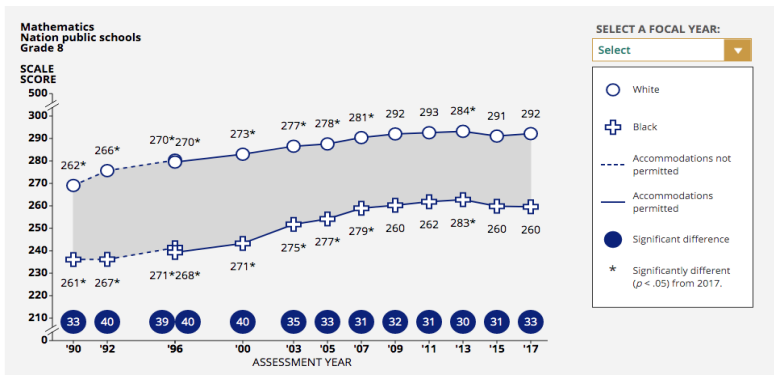

Figure 1. Mathematics scores for white and black students in grade 8 (compiled from NRC, 2017).
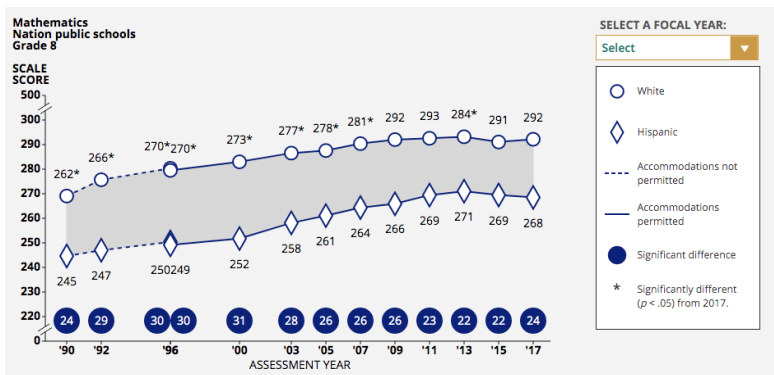

Figure 2. Mathematics scores for white and hispanic students in grade 8 (compiled from NRC, 2017).

Awareness of the ongoing gap in achievement between groups of students may contribute negatively to teacher expectations of certain groups. In fact, the belief that the achievement gap can be primarily attributed to factors that schools cannot control, such as student characteristics or home environment, has been found to be prevalent among teachers (Bol and Berry, 2005). Research has found that teachers tend to have significantly lower expectations of certain sub-groups, including Black, Hispanic, and low-income students (Ferguson, 1998; Boaler, 2002). Although teachers are often unaware of the bias behind these beliefs, Jackson and Delaney (2017) argue that "we use our beliefs, productive and unproductive, to make assumptions

and instructional decisions," which may explain the prevalence of basic-skills mathematics instructions in low-income, high-minority schools. In turn, this low-level style of instruction contributes to lower overall achievement for these students, creating a self-perpetuating cycle. This ultimately contributes to the under-representation of certain students in higher-level math courses and related career fields (Viadero, 2000). It is unjust to think of these students as under-achieving within a system that has failed to educate them for decades; instead, students belonging to these lower-achievement groups ought to be referred to as under-represented.
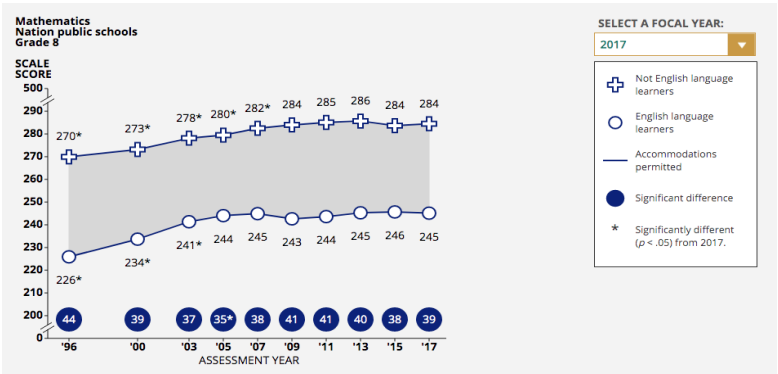

Figure 3. Mathematics scores for non-ELL and ELL students in grade 8 (compiled from NRC, 2017).
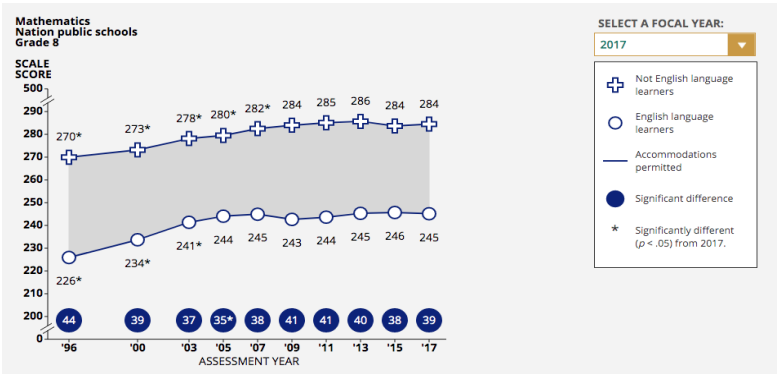

Figure 4. Mathematics scores for NSLP non-eligible and eligible students in grade 8 (compiled from NRC, 2017).

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To interrupt this cycle, a number of strategies can be employed to discover and combat biases and low expectations. These strategies are made more effective when a group of teachers and administrators from the same school engage in them together (Jackson & Delaney, 2017). Harvard's self-administered, online implicit bias test can reveal unconscious biases against certain groups (Fiarman, 2016). Biases identified by this evidence-based assessment can be confronted via exercises that build empathy for other cultural groups, such as reading journal entries written by students of color about their experiences as learners of mathematics (Fiarman, 2016). Teachers must also strive to understand the cultural background and individuality of each of their students, rather than relying on stereotypes as the basis of their interactions (Jackson & Delaney, 2017). Students internalize the stereotypes they experience from broader societal influences to shape their identities as math learners; it is the job of teachers to help students identify themselves as resilient learners of mathematics (Aguirre, Mayfield-Ingram, & Martin, 2013). Finally, it is vital for teachers to recognize their under-represented students' unique strengths in order to challenge "the common notion that students need to learn math in spite of who they are…students need to learn mathematics in light of who they are and the diverse gifts that they bring" to the classroom (Aguirre et al., 2013, p.10). As teachers begin to escape previously hidden unproductive beliefs about their students, they will become equipped to help their students escape them as well.

Equity in Problem-Based Learning

The idea of an equal education for all is a simplified version of the principle of equity. The National Council of Teachers of Mathematics defines equity as a key principle for effective math instruction, as described in the NCTM position statement on equity and access.

> Creating, supporting, and sustaining a culture of access and equity require being responsive to students' backgrounds, experiences, cultural perspectives, traditions, and knowledge when designing and implementing a mathematics program and assessing its effectiveness. Acknowledging and addressing factors that contribute to differential outcomes among groups of students are critical to ensuring that all students routinely have opportunities to experience high-quality mathematics instruction, learn challenging mathematics content, and receive the support necessary to be successful. Addressing equity and access includes both ensuring that all students attain mathematics proficiency and increasing the numbers of students from all racial, ethnic, linguistic, gender, and socioeconomic groups who attain the highest levels of mathematics achievement. (NCTM, 2014a)

It is important to note the distinction between equal and equitable education. Equality, as math teachers know, means two objects are identical; students receiving an equal education are receiving a set of instructional practices that are identical and indistinguishable. Equity requires more nuance. When teachers "[acknowledge and address] factors that contribute to differential outcomes," they must be focused on meeting the unique needs of each student, situated within all of their identities, within a system that chronically under-serves those belonging to groups described in the final sentence of the position statement (NCTM, 2014a). The work of addressing unconscious biases through awareness, empathy, and cultural understanding is an essential prerequisite to equitable instruction.

The three ingredients of equity that impact classroom instruction are high-quality instruction, challenging mathematics content, and support necessary for success (NCTM, 2014b). While the term "achievement gap" is useful for naming a statistical reality, it by implication blames students for their failure to achieve. Equity demands thinking of it as an instruction gap, which places the responsibility at the feet of the educators charged with teaching high-quality mathematics to all students. A teacher's choice of procedural, basic-skills instructional practices does not originate from malicious intent, but from the sincere, albeit misguided, belief that students from certain backgrounds are unable to "handle" a high level of mathematical thinking (Bol & Berry, 2005). On the contrary, faithful implementation of high-quality curriculum results in higher achievement for all students, but notably, has the important effect of decreasing racial and socioeconomic performance gaps (Schoenfeld, 2002). The proliferation of available high-quality curricula, such as the problem-based model authored by Illustrative Mathematics (n.d.; see https://curriculum.illustrativemathematics.org/MS/teachers/what_is_pbc.html), makes this kind of instruction viable for in-service teachers.

Presenting challenging mathematics content to students requires teachers to revise existing beliefs about what constitutes success in mathematics. Part of the allure of routine instruction is students' ability to emulate processes with admirable precision in spite of a lack of understanding of the underlying concepts. Causing struggle is difficult for teachers who are accustomed to this shallow kind of success, and the skill to balance the challenge so that students engage in productive struggle without giving up approaches an art form (Smith & Stein, 2011). Many teachers also resist the notion that students can learn the procedural fluency they need from engaging only with problem-based mathematics. This fear has proven to be unfounded, since students receiving this kind of instruction showed gains in both problem-solving and in basic skills, even when the latter was not emphasized outside of problem contexts (Schoenfeld, 2002).

Determining the support necessary for student success is a key component of creating equitable math classrooms. Ongoing debate about the most effective format of curriculum often neglects to consider how the curriculum is implemented; the key factor is the skill of the teacher in connecting the mathematics learning intended to the actual learning outcomes achieved by their students, regardless of curriculum (Boaler, 2002). Smith and Stein (2011) describe five practices that can make the difference between a mathematics classroom in which discussion is disconnected talking and one that connects intended to actual learning; the teacher must anticipate student responses, monitor student work in class, select student work to

focus the discussion, sequence the mathematical ideas that will be discussed, and connect the discussion to the mathematical learning that was its objective. Teachers making these kinds of instructional moves are already exhibiting a great deal of skill, but must take additional steps to ensure that the result is truly equitable, as we will see in the following vignette.

Teacher Practices for Equity

Ms. Clark is a fifth-year teacher who has intentionally sought to understand her students' cultural backgrounds and confront her own biases as she teaches in an urban school in a mid-size midwestern city. This is the first year she has implemented a problem-based curriculum in her grade 8 math class. Twenty-two students are seated in groups of four or five, which are randomly assigned several times within an instructional unit. The learning objective is printed clearly on the board: "Write the equations of lines in y=mx+b form, and explain where to find slope and vertical intercept in both an equation and a graph."

After a brief warm-up activity that helps students recall the definition of geometric translation, Ms. Clark introduces the first activity of the day by asking for a show of hands to answer, "How many of you have earned money from another family paying you to do something?" About half of the hands in the room go up, and a small burst of chatter occurs at one table. Ms. Clark only catches the last part of the exchange.

Jaden: I get bread, don't worry about it.

Ms. Clark: Raising hands does not mean opening your mouth, Jaden. Ok, let's try an actual silent response this time. How many of those jobs were babysitting? (A few hands go back up). So that's the job Diego has in this situation. He earns $10 per hour of babysitting and is keeping track of his earnings. Question about that, Malena?

Malena: Does he always babysit the same number of kids? If I babysit my cousin's three kids I charge more.

Ms. Clark: That's a good example of how real life can be more complicated than a math problem. Let's think of the $10 per hour as being a general model for how much Diego earns. Do you remember what a model is?

Malena: It's like, well, we make things easier so that we can understand them better, when we do the math for it.

Ms. Clark: Right, when we model, we keep things simple to focus on the math. So maybe Diego earns more or less for different families but it evens out to $10 per hour. Any other questions about how that works? Ok, for this problem, you will spend a few minutes working on your own to answer questions 1 through 3 before sharing with your group. Then answer question 4 together.

The students silently read the following question prompt (Adapted from Illustrative Mathematics, Grade 8, Unit 3, Lesson 8).

1.   Diego earns $10 per hour babysitting. Assume that he has no money saved

before he starts babysitting and plans to save all of his earnings. Graph how much money, y, he has after x hours of babysitting.

2. Now imagine that Diego started with $30 saved before he starts babysitting. On the same set of axes, graph how much money, y, he would have after x hours of babysitting.

3. Compare the second line with the first line. How much more money does Diego have after 1 hour of babysitting? 2 hours? 5 hours? X hours? Explain.

4. Write an equation for each line.

Ms. Clark sets a visible timer to indicate when silent work time ends and begins to circulate the classroom, carrying a clipboard with her.

Connecting mathematics to students' cultural backgrounds and experiences requires knowledge of students. The task used is an appropriate context for the grade level, and Ms. Clark solicits student responses knowing that working for others is a common experience for her students. Malena's response was rooted in her experiences and was not mathematically relevant, but Ms. Clark connected it to the practice of using mathematics to model. Jaden's off-task comment also derived from his culture in a way that Ms. Clark may have been unprepared for, creating an opportunity for her to understand her students better by finding out the reasons for his defensiveness, including what was said to him to prompt his comment. Not every mathematical activity can relate directly to students' culture, since many abstract topics have no analog in the daily life of a teenager. Instead, teachers should focus on students' mathematical strengths as the main point of connection (Jilk & Erickson, 2017). Ms. Clark provided a definition of modelling since Malena's definition was vague, but the learning community in the classroom would have benefitted from hearing the definition clarified by a student who has an affinity for putting mathematical ideas into their own words.

Ms. Clark's clipboard is significant in her implementation of Smith and Stein's (2011) five practices, outlined previously. The focus of the lesson is printed at the top of the page, along with anticipated correct and incorrect student responses. In order for the discussion to be productive, the teacher cannot be an idle observer nor a taskmaster, but must instead prepare to connect student work to mathematical ideas by intentionally monitoring student work and making decisions about which mathematical ideas should be selected for discussion and in what order. These monitoring sheets, completed for each class of students, can be a useful resource for equity, since they serve as a record of which students have been full participants in the construction of mathematical learning (Jackson & Delaney, 2017). Dynamics within groups can also be recorded for the purpose of teaching students to work well with all of their diverse peers. Randomly selected groups is an example of a classroom system that combats bias by removing the human element from seat assignment (Fiarman, 2016). In the next part of the vignette, Ms. Clark checks in with one of her randomly selected groups.

The timer rings, indicating the end of individual work time. Ms. Clark has made notes

and intervened with a few students' minor misconceptions, and now releases the students to work as groups to write equations for Diego's babysitting situation. She notices one group, composed of Alice, Jordan, Tyler, and Jaden, is not talking and investigates. A quick survey of their papers shows that the students have not compared the graphs they each created, and only Jordan has an explanation for question 3.

Ms. Clark: How is this group doing? Jaden?

Jaden: We're done.

Ms. Clark: Ok, can you tell me about the equations you wrote?

Jordan: Well the first one is y=10x and the second one is y=30x.

Ms. Clark: How do those equations relate to the graph, Tyler?

Tyler: I don't know but it's what Jordan said and he is probably right.

Alice: I'm not sure, because if it was 30x, wouldn't the second point be at $60? I think it is at $40.

Ms. Clark: Tyler, what do you think about what Alice said? (pauses; Tyler is frowning at his graph now). All of you, move your papers to the middle so you can all see each other's graphs. Jordan, please think aloud with your group about what your equations mean so they can decide if they agree with your ideas, not just your answer.

Ms. Clark notes that the group responded to her reminder of class norms before moving on to check the work of other groups, looking for students who used tables, points, or verbal descriptions to create their graphs and equations. As groups approach the goal of this activity, Ms. Clark jots quickly at the bottom of the page: "Jaden disengaged."

In this interaction, Jordan engaged in what Lampert (1990) described as keeping thinking implicit, common for students who are accustomed to having their quick, usually correct responses accepted immediately and unquestioningly by their peers and teachers. The discipline of defending answers using mathematical reasoning deepens understanding for both the individual explaining their work and their peers. Jordan's peers deferred to him as the "expert" in their group, a role that is quickly sussed out by students like Tyler who are habitually passive in math, content to wait for someone else to tell them how to do it or what the answer is (Lampert, 1990). This power dynamic also leads to the silence of out-numbered voices like Alice's. The norms of everyone being able to see each other's papers and understand each other's work gives all students access to deeper understanding of the concept being presented (Jilk and Erickson, 2017). Teachers must also understand that student perceptions of peers as experts are certainly influenced by the same biases that shape their own identities as math learners (Aguirre et al., 2011). Ms. Clark's intervention disrupted the power dynamics of the group, because she understands that "teachers have an essential role in equalizing the power when the societal norms have oppressed certain students" (Jackson & Delaney, 2017, p. 149). Regardless of

their students' demographic groups, teachers cannot abandon their role in promoting equity.

A disengaged student requires further attention. Recalling her brief, justified correction of Jaden's off-task comment, Ms. Clark may attribute his reticence in engaging in group work to that negative public interaction. However, she may not be aware of her patterns of correction or the ways that Jaden experiences them. Perhaps he is chronically singled out when a peer was engaging in the same behavior, or perhaps the public nature of the correction transgresses a cultural identity. Minor discipline corrections and other moment-by-moment decisions are the most difficult to self-monitor and thus the most vulnerable to unconscious bias (Fiarman, 2016). A trusted outside observer or video-recording can facilitate self-reflection about these kinds of decisions. Jackson and Delaney (2017) describe a training process that focused on how the teacher engaged students on the concept, explained the concept to groups, responded to misconceptions, and addressed off-task behavior, and whether there was variation in the teacher's interaction in these domains with various sub-groups of students. Observing their peers within this framework allowed teachers to notice their own inconsistencies in interaction with under-represented students, in ways that they commonly found surprising (Jackson and Delaney, 2017). This reflects the reality that biases are hidden from their owners but influence instructional choices in subtle ways, distinguishable only to those it harms.

Conclusion

For teachers who aspire to meet the principle of equity in their practice, the lack of success can sometimes be confounding. However, best intentions cannot overcome our unconscious biases, which require dedicated effort to recognize and address. This work must carry over into classroom practice through intentional actions such as those described in relation to Ms. Clark's vignette. Although equity is a challenging principle, the better outcomes for all students make its pursuit worthwhile.

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About the Author

Emily Mylek earned a B.S. in Mathematics Education from BGSU in 2011 and an M.A.E. in Education and Mathematics from UT. As a middle school math teacher at Toledo Early College, Emily's goal is to promote equity in access to high-level mathematics for all students.