ICEBERG OF CULTURALLY RELEVANT MATHEMATICS AND SCIENCE PEDAGOGY: A PEDAGOGICAL AND ANALYTICAL TOOL FOR TEACHER EDUCATION

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There is a clear need for an operational framework that captures the difficulty of implementing culturally relevant pedagogy (CRP) and supports teachers to imagine new forms of pedagogy. In this report, we present the Iceberg of Culturally Relevant Mathematics and Science Pedagogy (CRMSP), a tool, grounded in the tenets of CRP, that delineates practices ranging from the most accessible and easy-to-implement, to the most subversive yet arguably the most significant in terms of their potential to re-characterize the acts of doing and being competent at mathematics and science. We provide examples of CRMSP that re-position marginalize learners in relation to mathematics and science. We discuss the levels in which this tool can serve to disrupt dominant, inequitable systems of instruction and preview ways it can support teachers' efforts to provide meaningful mathematics and science learning experiences for youth.

Keywords: Culturally Relevant Pedagogy, Preservice Teacher Education, Teacher Knowledge, Curriculum

Like other social institutions, schooling has served to disenfranchise and subjugate students of color and their families, and to reaffirm a white ideology that supports white students, teachers and families (Emdin, 2016; Leonardo, 2009; Picower, 2009). Scholars and practitioners have explored ways to confront the inherent racism that permeates schools and have developed critical frameworks such as culturally relevant culturally relevant pedagogy (CRP), culturally responsive teaching and culturally sustaining pedagogies (Paris & Alim, 2014; Ladson-Billings, 1995, 2014; Gay, 2002).

In this report, we describe our work with a teaching protocol that both supports the identification of CRP and the analysis of these practices within the context of culturally relevant science and mathematics classrooms. This approach to understanding *Culturally Relevant Mathematics and Science Pedagogy (CRMSP)* asks preservice teachers (PTs) to use readily identifiable practices and materials and then scrutinize them for how compatible or tenuous they are with CRP. For the final analysis of compatibility/tension, we use the idea of a continuum of criticality from the Iceberg of Culture (Hall & Hall, 1976; Weaver, 1986) to assist PTs in analyzing their own materials, dispositions and practices. To analyze, visualize, and develop responses to the challenges and limitations surrounding PTs' implementation of CRMSP, we use two theoretical frameworks: critical whiteness studies and the iceberg of CRMSP.

Theoretical Perspectives: Culture and Whiteness

Equitable teaching requires PTs be able to analyze their own teaching and to be able to speak clearly about where and how they are supporting all learners and recognizing inherently racist practices. Doing this with efficacy requires a deep understanding of whiteness and the many structurally racist practices that are often "invisible" to white educators (Leonardo,

2009). Supporting PTs to becoming culturally relevant practitioners demands that PTs be able to identify emergent, intermediate and advanced culturally relevant practices in STEM.

Inextricably connected to whiteness, we consider an understanding of culture and how that influences what teachers are willing to do pedagogically. If PTs have a shallow understanding of culture, it is going to be difficult for them to teach in culturally relevant ways. If PTs see culture as *only* stereotypical examples of food, holidays and celebrations, it is going to be challenging for them to see how they reinforce dominant oppressive practices. It also will be exceedingly difficult for PTs to fully understand, both theoretically and practically, the role of culture in equitable science and mathematics teaching and learning (Nasir, Hand & Taylor, 2008; Nasir & de Royston, 2013).

Research Design, Context, and Methods

This work is situated in urban teacher education programs explicitly focused on developing anti-racist, culturally relevant teachers. Major program goals are to develop critically conscious PTs who understand how whiteness permeates schools and classrooms. The PTs we reference in this report are both elementary and secondary students from alternative certification programs.

Using the frameworks above and our experiences with PTs we developed a series of activities for helping PTs better understand and enact CRMSP. Described below, the activities first ask teachers to identify concrete elements of their practice (curricular materials, instructional decisions and teacher dispositions). This is followed by mapping the teacher practices back to the tenets of culturally relevant pedagogy. Finally, we follow this with an alignment of the teacher practices on an "iceberg of CRMSP" to assess the criticality of the practices (see Figure 1 below).

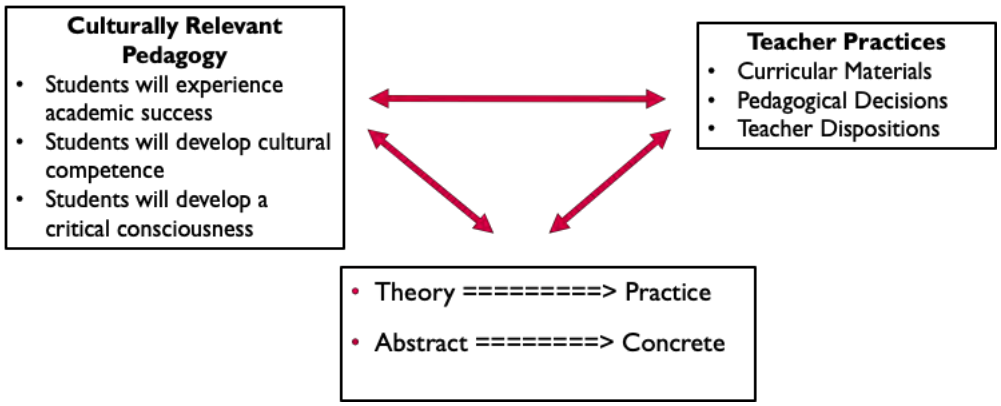

Figure 1: Supporting Teachers to Operationalize CRMSP

Data Sources

The data sources we draw upon include collaborative documents used in class (where PTs document CRMSP), lesson plans that PTs wrote, notes from debriefing sessions with PTs, and PTs' responses to reflection prompts used in class. The data was examined through the lens of culturally relevant pedagogy, specifically how each of the classroom events represents the tenets of CRP and what impact this event would likely have on dramatically shifting the experiences and success of children of color. In this analytical process, we relied heavily on our professional experiences as teachers and teacher educators, and our knowledge of the literature and judgement

as to the degree to which PTs were moving beyond superficial notions of culture and critical pedagogy.

Results

As discussed above, PTs overwhelmingly support the *idea* of culturally relevant teaching, and they can, after study, articulate and operationally define the tenets. A disconnect comes when PTs are asked to analyze their own teaching through a CRP lens and identify how they are enacting or plan to enact CRP.

Components of Teaching in Culturally Relevant Ways

The three categories of teacher practice (curricular materials, instructional decisions and teacher dispositions) represent a bridge between the visualization of culturally relevant pedagogy and actual classroom interactions, and potentially offer PTs a way to access a critical analysis of their own science and mathematics teaching. The analysis is embedded within the course that the PTs take. For example, as a class assignment PTs read and analyzed Ladson-Billings' (1995) article, "But That's Just Good Teaching." PTs studied the concept of culture by working on their own understandings of culture and CRP. The analytical tool described here evolved out of this work with PTs and the provocations put forth by Ladson Billings (1995, 2014) and others (e.g., Gay, 2018; Paris, 2012).

In the first step of the analysis PTs are asked to list curricular materials, instructional decisions, and teacher dispositions for a lesson they are developing, have observed, or are going to teach. Some of the listings are easily evident, such as the use of a textbook (curriculum material) or the decision to move to small groups for problem solving (instructional decision). Others, such as how a PT responds to a student's question or "misbehavior" (teacher disposition) are more difficult to identify. We now recognize that the "difficulty" of identifying a practice is linked to the criticality of the practice and that the practices that PTs choose to "not see" are those that often reinforce a white, hegemonic classroom (one example from our practice and research is described below). Despite this recognition, the list offers PTs a series of things to analyze. Once a PT has listed a textbook as a curricular material, the conversation about the textbook begins and opportunities for discussion about what culturally relevant pedagogy looks like continues.

Curricular Materials. *Curricular materials* refer to any physical artifacts or resources that a teacher may use in class. These include, but are not limited to: trade books, textbooks, videos, speakers, handouts, worksheets, and manipulatives. PTs can quite easily identify the concrete curricular materials that they use. Once the PT has identified the curricular material we ask, "How does this choice connect to one of the tenets of CRMSP?" For example, a student teacher, Ned, chose to use an article from *The Atlantic* entitled, "The Myth of 'I'm Bad at Math'" (Kimball & Smith, 2013) after his middle school students took their first math exam. Ned was worried that the students did not see themselves as "good" at math and wanted to challenge the idea that some people are "just good" at math. In our class google doc, where we recorded our examples, Ned explained how the use of the article connected to the tenet of "academic success." Ned was considering how effort makes a much bigger difference in mathematical academic success than we tend to give it credit for, especially in middle and high school. Ned's example offers an opportunity to see how something as simple as a magazine article can be used as evidence of CRMSP. The example also reinforces the idea that the tenets *matter* and that PTs can think about them as a way to dig into what it means to be a culturally relevant teacher. The article also pushed the idea of "culture" since it is not specifically tied to the traits that PTs think of as culture (e.g., holidays, stereotypes, food, etc.). In this way it opened up a place for a

conversation about how we can analyze our teaching using a CRMSP lens. It allowed us to talk about how society views "who can do math" as a cultural component. It also begins to set the stage for PTs to push themselves. In this example the connection to academic success is legitimate but it also generates the question, "What about cultural competence and critical consciousness?" Continuing to reinforce the idea that CRMSP *is* all three of the tenets is an important component of this work.

Instructional decisions. Instructional decisions refer to the ways in which teachers engage learners with curriculum. These include the structure of lessons, teacher moves in lesson delivery, managing participation patterns, orchestrating classroom discourse, collecting evidence of student learning, and overseeing interpersonal dynamics. Like curricular materials, instructional practices can be designed for white students (consciously or unconsciously) and guided by school or district-level initiatives, or they can be designed with equity and justice in mind. Our goal is to have PTs identify their own or other teachers' instructional decisions and then to connect them to the tenets of CRP.

Below we describe an observation with Sharon, a student teacher teaching a math lesson to 2nd graders. To prepare for the observation Sharon wrote a lesson plan which included a section specifically addressing culturally relevant pedagogy. She was asked to reflect on how her instructional decisions connected to CRMSP. She wrote:

> I am using a cognitively guided approach. Students will be leading the lesson with their thinking, and I will be able to better scaffold based on what I learn from the process. Rather than open with an algorithm, I want the students to tap into their number sense and sense-making skills to understand the thinking behind the function.

In this example Sharon identifies cognitively guided instruction (e.g., Carpenter et al., 2015) as the foundation for her math lesson. She is intentional about centering student thinking, which reveals her commitment to the value of her students' mathematical ideas, a component of CRP, and articulates how she will engage the students in the content. When asked to move from the concrete to the abstract, from the actual instructional decision to the tenets, Sharon writes the following as a rationale for the instructional decision:

> Soon, students will be introduced to two-digit subtraction with borrowing. Before this happens, I want them to get a better understanding of the math thinking behind the algorithms they will need to learn. I will use a Cognitively Guided approach to present them with a story problem and allow them to work in small groups to find a solution in a way that makes sense to them. The story problem is also based on their literacy text for this week. This way they have background knowledge that contextualizes the math problem and makes it easier for them to connect with. I will not be showing them the algorithm for solving an equation with borrowing. I will be walking around the room, checking in with groups, and asking them questions about their methodology and if their answer makes sense to them. I anticipate that many students will attempt to solve with addition or the improper use of an algorithm, so I will use some talk moves to try to guide them to question their own work and find another way. At the end, we will share what we did to find an answer. We may not arrive at the "correct" answer, but I will get several examples of student thinking that I can use to build upon as we move forward with math instruction.

In Sharon's rationale we can hear how she is building a theoretical base for her teaching. While not explicitly described in her lesson plan, in our debrief after the session we make sure to discuss how the instructional decisions made connect to both academic success and cultural

competence. Like the in-class discussions with PTs the debriefs following teaching observations are critical spaces for productive talk about the connections between concrete teaching practices and the tenets of CRP and CRMSP. Often the PTs themselves are not even aware of how they are making these connections in practice. In this case since the use of cognitively guided instruction did not necessarily resonate with Sharon's idea of "culture" she did not recognize using it as evidence for CRMSP. During the debrief we highlight how Sharon's encouraging students to share their sense-making, being open to ideas that students share and facilitating student-to-student talking opportunities, are actual components of culturally relevant math teaching. We want to make sure that Sharon realizes that she is pushing back on the widely used math practices of teacher directed algorithmic memorization for problem solving and is instead demonstrating an actual practice that supports both academic success and cultural competence. Talking with Sharon also creates an opportunity for discussion about the critical consciousness tenet that is not addressed. During our debrief with Sharon, like discussions with Ned, we brainstorm how the lesson can be extended to interrogate something in the students' community or to investigate an injustice.

Teacher dispositions. Teacher dispositions refer to the beliefs about, and behaviors toward children, science, and/or mathematics that shape teachers' decision-making and interactions. With regard to our own science/math teacher education pedagogy (Willey & Magee, 2019), we believe that PTs are more likely to develop an awareness of their, often unconscious, biases if they are consistently asked to reflect on how and why they operate as they do. In discussions with PTs we often ask: How do you/teachers respond when students offer answers that do not match your/their expectations? How did you/teachers respond when students are disengaged or resistant to instruction? How do you/teachers perceive how math and science should be taught in schools and how are these ideas discussed with students? What behaviors do you/teachers display when motivating students to engage in challenging curricula?

Teacher dispositions can be framed as how educators respond to students at various moments. Teacher dispositions, like curricular materials and instructional decisions, are often rooted in long-established, oppressive and racist practices that PTs replay with little scrutiny or awareness. Intentionally including teacher dispositions has the potential to push PTs to look beyond curricular materials used to see CRMSP. Dispositions reveal how underlying beliefs about science and mathematics intersect with views of students, and how these beliefs are externalized in messaging about the importance of science and mathematics and students' success with the content. It is the identification of these dispositions and further analysis of them that offers PTs a way to scrutinize and grow their own teaching practice.

To illustrate teacher dispositions in practice we share Trevor's story. Trevor is a secondary alternative certification student studying to be a science teacher. After learning about CRP and CRMSP he used the categories of curricular materials, pedagogical decisions and teacher dispositions to mine his practice for evidence of CRMSP. He shared the following vignette in a written assignment that was shared with his classmates:

> After being out of the classroom for over a month (and being out of their medication for a longer time) the student was disengaged from what we were doing in class. This student has ADHD and with it has difficulty focusing during a note taking session. During this time, I gave the student the notes but filled in, so they can work ahead or go back in case they missed something and sat them in the back of the room on some comfortable furniture. Since doing this, they have taken all of their notes, actively participated during class time, and has not distracted other students during this time.

Trevor described his actions as supporting the student's academic success through the use of a pedagogical decision - using prepared notes in class and offering a comfortable physical space for the student to work. However, in class discussion with Trevor, it was clear that his teacher dispositions were *also* important here and warranted analysis and discussion. By sharing the prepared notes and finding ways to include the student honorably, and without humiliation, Trevor demonstrated his ability to be supportive and to do whatever needed to be done to re-engage the student. Importantly he did this without bribes, threats or negative talk to the student.

Trevor's story presents an opportunity to talk about the often unanalyzed dispositions that are so difficult for PTs to name. Bringing out and interrogating the dispositions was a key goal for the classroom discussion which occurred during a student teaching seminar. After Trevor shared his story in seminar the following question was posed, "How can the frame of whiteness and cultural norms help us analyze Trevor's vignette?" Given that the story doesn't center race or culture explicitly, the PTs were asked to consider the importance of whiteness and cultural norms in this story. Helping PTs see that race influences and informs all that we do as teachers, especially the often "invisible" dispositions, is a critical component of the preparation program goals. Supporting PTs to see where and how they are negatively impacted by whiteness as well, as then they are resistant to its trappings are difficult skills to develop and take time. We will often ask, "What does this have to do with Whiteness at all?" The PTs know that Trevor is a white male and the student in the vignette is Black.

Iceberg of Culturally Relevant Mathematics and Science Pedagogy

The Iceberg of Culturally Relevant Mathematics and Science Pedagogy (see Figure 2 below) is used to illuminate the complexities of internalizing and enacting CRMSP in school settings, where there is little space readily afforded teachers to innovate and create STEM learning experiences grounded in cultural knowledge and experiences. Moreover, the Iceberg of CRMSP expands the rigid and problematic boundaries of how science and math teaching and learning have historically been characterized.

Like the Iceberg of Culture, the top of the Iceberg of CRMSP includes visible teaching practices that are of low emotional load. These curricular materials, instructional decisions, and teacher dispositions are the most accessible for teachers to employ and the least likely to create friction in school settings, where teachers are often closely surveilled. For example, common practices at the top of the iceberg include, celebrating holidays, using students' names and hobbies in word problems, and using texts and trade books that include diverse characters or historical figures. The use of these types of strategies is not bad, and these are, in fact, the ones that our PTs often use. What we find worrisome, and what we use the iceberg metaphor for, is to help our PTs see that these practices sit at the top of the iceberg in an area of low emotional load. They are generally not controversial, and, while not insignificant, they do not really push into a critical space where the status quo is challenged and reshaped. Pedagogically speaking, they are an acceptable place to start but not where we want our PTs to stay.

The teacher practices in the middle of the iceberg are more emotionally challenging and observed less often in science and math classrooms than those at the top. They represent a level of cultural engagement and awareness more emblematic of CRMSP. These practices draw on more fundamental aspects of students' cultural lives, including invisible cultural practices.

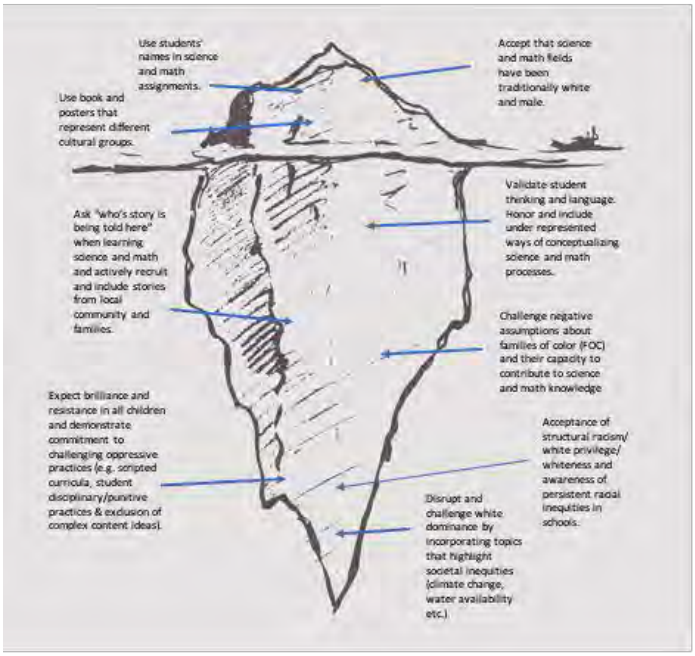

Figure 2: Iceberg of Culturally Relevant Mathematics and Science Pedagogy

Finally, the teacher practices closest to the base of the iceberg are the least likely to be observed in science and math classrooms and are arguably the most tenuous to enact. These moves indicate a strong political and racial consciousness, and a profound understanding of CRP. These practices demonstrate a commitment to all tenets of CRP and to a version of science and math education concerned with the critical science and math identities of the students. For example, one example that we highlight in Figure 2 is "Expect brilliance and resistance in all students and demonstrate commitment to challenging oppressive practices (e.g., scripted curricula, student disciplinary/punitive practices, exclusion of complex content ideas)." In practice this looks like teachers pushing back against skill-based and white-washed curricula and demanding that *all* their students become engaged in learning.

Discussion and Conclusions

Mathematics and science educators have been exploring CRP for at least two decades (e.g., Barton, 2003; Johnson, 2011; Willey & Magee, 2019; Vazquez Dominguez, Allexsaht-Snider, & Buxton, 2018), but it is clear that much work remains to be done. Resistance to change is not surprising given the pervasiveness of structural racism, including how mathematics and science teacher organizations have long appealed to white sensibilities (e.g., Martin, 2015). Preparing new teachers is particularly challenging since most PTs bring to their preparation program unchallenged experiences that support westernized perceptions of math and science, white supremacy, anti-blackness and a superficial understanding of (cultural) difference. As teacher educators immersed in equity work for over 10 years, it is hard to accept the limited progress that PTs make in a year or two of a preparation program. Our response to this dilemma has been to commit to the framework of CRMSP, trusting in the idea that as PTs explore the tenets and CRP holistically, they have the greatest chance of developing long-lasting commitments to racial justice and equitable teaching for all their students. We see that time invested in operationalizing

the tenets, interrogating their own cultural identities, and exploring what CRMSP looks like *in practice*, has the potential to support PTs in their long-term development as critical practitioners.

The two-pronged approach that we outline here is grounded in our acceptance that PTs need support as well as opportunities to understand CRMSP. We do not see these activities as a simple protocol, but rather as a way for PTs to understand and internalize the dimensions of CRP, develop a stronger sense of their impact, and to serve as a roadmap for how to live them in real life. We recognize the inherent danger in "breaking down" a framework into manageable pieces as a way to teach it. This is indeed how complex ideas become shallow and superficial (Ladson-Billings, 2014). With this in mind we are mindful of constantly returning to the idea that CRP and CRSMP are not complete without all of the tenets. Working with PTs to see how the concrete and abstract come together - and the theoretical and practical - is the goal of this work.

Supporting PTs to reflect on and analyze their own teaching through the lens of CRP is a critical piece of developing critically conscious teachers. We are hopeful that the approach we describe here can guide research investigating mathematics and science teachers' learning about and implementation of critical pedagogy, and be used within teacher preparation programs and professional development settings to support humanizing, culturally relevant mathematics and science teaching.

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