Culturally Relevant Pedagogy in Science: The SCI-Bridge Model

Scholarly paper presented at the

2021 American Educational Research Association Annual Virtual Conference

Diane Truscott, Brian Williams, Nancy Jo Schafer, Ana Solano-Campos, and Stephanie Byrd

Georgia State University

Abstract

Urban Title I schools need teachers who recognize and can help address challenges with broadening participation in science and inequities in access to quality science instruction found in elementary schools. The paper presents scholarly work supported by a National Science Foundation Discovery Research K-12 grant. A new science instructional model that intersects effective practices in science education with the theoretical principles of culturally relevant pedagogy is provided. Grounded in evidence-based practice, the new model, *SCI-Bridge*, features how culturally responsive classroom management, facilitated discourse, and contextual anchoring can be implemented as part of science instruction in elementary classrooms.

Keywords: Culturally relevant pedagogy, science instruction, urban schools

Culturally Relevant Pedagogy in Science: The SCI-Bridge Model

In this paper, we present the *SCI-Bridge Model,* a new science instructional model that intersects effective practices in science education with the theoretical principles of culturally relevant pedagogy. Grounded in evidence-based practice, the SCI-Bridge model features how 1) culturally responsive classroom management, 2) facilitated discourse, and 3) contextual anchoring can be implemented as part of science instruction in elementary classrooms. First, we present a vignette that illustrates the ways in which these three principles are enacted in a culturally and linguistically diverse SCI-Bridge classroom. Then, we unpack the vignette to present and discuss each of the components of the model and their implications for science education.

A Glimpse into a SCI-Bridge Classroom

Ms. Adanya is a 5th grade teacher at an elementary school in Atlanta, Georgia. This year, her class is composed of a group of energetic and curious children from local neighborhoods near the school. Last summer, Ms. Adanya was introduced to the SCI-Bridge model in a summer program sponsored by a grant from the National Science Foundation. She has been using the model in aspects of her practice, but especially during her science instruction in conjunction with the 5Es framework (Bybee, 2009). This includes the use of Culturally Responsive Classroom Management strategies to build and maintain safe and healthy classroom communities, establish clear and consistent expectations, and utilize language that supports student learning, cultural competence, and critical consciousness. Today, Ms. Adanya is starting a new science unit on water. Today's lesson will launch an investigation on content related to the following Next Generation Science Standards:

5-ESS2-2. Describe and graph the amounts of saltwater and fresh water in various reservoirs to provide evidence about the distribution of water on Earth.

3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

Ms. Adanya is particularly excited about this content. In addition to the science content, she knows that many of her students live in communities that face challenges related to water. These include access to clean water, flooding and poor water management, and drought. She also knows that people of color and poor people around the world face similar challenges. For example, 1 in 3 people globally do not have access to safe drinking water. In the United States, stories of communities in Flint, Michigan and Standing Rock in the Dakotas have both clashed with corporate and government organizations over access to clean water. For Ms. Adanya, the content related to water extends beyond the science textbook and into the history, lives, and cultures of her students and the communities in which they live.

The Invitation

Ms. Adanya recognizes that all of her children have some prior knowledge about water. Understanding this, she decides to invite her students to the lesson with a simple but interesting question: Where in the world is our clean, fresh water? She hopes that the question will inspire questions and curiosity but also activate her children's prior knowledge. As students respond, she reminds them of the value of thoughtful responses, active listening, and purposeful questioning.

In the supermarket. You can buy it.

At my house. It comes out the sink.

You can drink the rain...before it hits the ground.

That's dumb, isn't it acid rain?

Ms. Adanya interjects to remind the class of the classroom ground rules they help create in order to have a safe space to risk. "Remember class to use our words respectfully so that everyone is willing to participate. There are no dumb ideas in science class. Jason, try that again?"

Yes. Is there acid in all rain water?

Rivers. Like the Chattahoochee.

In the toilet. (Laughter)

Ms. Adanya creates a list of brainstormed ideas on the whiteboard and prompts with additional questions. They continue to share ideas and discuss what they know. While there is consensus about some sources, there is disagreement about some other ideas. For example, some students don't think that snow should be included on the list because "you can't drink ice." Others disagree with the idea that water can be found underground or in the sky. Ms. Adanya is excited by the conversation and the ideas her students are sharing. After a bit more discussion, Ms. Adanya lifts a 5 gallon bucket onto the table in front of her. "This bucket has 5 gallons of water in it. Let's imagine that this represents all of the water on the Earth. Everything that is on our list and more. How much of this would be fresh water?"

About half the bucket.

Most of it...maybe…

I don't think so, the oceans are salt and they are big.

I think just a little bit. Like a spoonful.

Using a measuring cup, Ms. Adanya scoops out two cups of water from the bucket and pours them into a clear cup. She holds the cup up. “It turns out that only about two cups would be fresh water. The rest would be salt water.”

That’s what I said. And we can’t drink that.

“Yes. But it turns out that we can’t really drink all of the freshwater on the Earth. A lot of it is frozen.” Holding up the clear cup of water, Ms. Adanya asks “How much of this freshwater of Earth would be available for us to drink”

About half?

I’d say just about a quarter...one fourth.

I’m sticking with a spoonful.

Using a measuring cup, Ms. Adanya scoops ½ cup of water from the clear cup and pours it into another clear cup. Holding it in front of the class, she says “That’s it. About ½ a cup would be fresh water that is available for us to drink, ½ cup from the 5 gallon bucket. That’s it.”
Gasps of surprise move through the classroom. Ms. Adanya watches as her students carefully consider what she has just presented. They’re thinking. They’re wondering. Now, their hands shoot above their heads signaling what Ms. Adanya planned for: They’re questioning!

Is that enough water for everybody in the world?

Can we make more water?

Why can’t we just melt the ice and drink it?

Can we clean dirty water and make it freshwater again?

The Exploration

The next day Ms. Adanya reminds the students about the amount of clean, freshwater that was available to drink and poses a new guiding question to the class. “If this is all the freshwater we have to drink, how do we clean the water that we use. For example, what happens to the water that you drain from the bathtub after you take a bath...that goes down the sink after you wash the dishes... that you flush down the toilet after you use the bathroom?" Students draw pictures of what they think happens to water after they use it in their homes while Ms. Adanya asks questions that inspire students to think in different ways about their drawings and the ideas that inform them. In small groups students present their ideas to one another and are encouraged to ask questions or make statements about their classmates drawings. This is one way Ms. Adanya is nurturing communities of discourse that center student voices and ideas. As groups report out on some of the things they learned in their groups we hear,

We think that there are pipes that take our water away.

Like under the sink.

We said the same thing. We think they go to the sewer on the street.

Where Pennywise lives!

There's a place on Bolton Road where they clean the water. It probably goes there.

Ms. Adanya collects their ideas on the whiteboard and exclaims "We all agree that somehow the water moves from our home - probably by pipes - and goes to a place where it is cleaned. Somehow - maybe by pipes - it gets moved back to our homes. That's what we think. Let's talk about the cleaning process. Let's explore how that might work." She carefully places bottle after bottle of mirky, brown liquid on the table in front of her and explains the basic idea behind a water filter. Students are introduced to sand, rocks, cotton balls, cups, spoons, coffee filters, rice, gravel, and activated carbon and asked to build and test water filters. Small groups work on their filters to develop different ideas and discover the most effective design. Ms Adanya reminds the groups of their Essential Agreement - the list of expectations that the class community developed earlier in the year. The list includes - Leave our space better than you found it, Share the mic, and Be prepared to do great things. Finally, Ms. Adanya gives instructions for collecting and working with the materials. “We don’t have an unlimited supply of materials so we need to be thoughtful about how we use them. Before you collect any materials, let’s spend some time thinking and talking with each other about how we might use the materials to build a filter. Put your ideas on paper. Draw a picture. Make a diagram. Let’s take a moment to plan before we build.”

The classroom buzzes with energy as students move into their groups and begin discussing their ideas. Ms. Adanya moves from group to group listening to conversations, asking guiding questions, and observing the group interactions. She scribbles notes on a legal pad she carries with her. Her notes range from important conceptual ideas she wants to revisit later to the progress of individual students to changes she will make to future interactions of the lesson. The classroom hums as students begin to build. When the hum grows to a growl, Ms. Adanya reminds the classroom community of one of their Essential Agreements - Consider the needs of others - and points out that students in other classrooms will be disturbed if their conversations are too loud. The classroom returns to a hum as the students continue to build.

As each group presents their functioning water filter, other groups listen actively, ask questions, take notes, and compare their model with the one being presented. Some students also make suggestions about how a group’s design can be improved or offer applause when a group’s filter performs exceptionally well.

You definitely need a coffee filter. It catches everything!

But you can’t just use a coffee filter. You need more.

I like the idea of stacking stuff..like a layer of this then a layer of that.

That works good. It also helps if you put the stuff with big holes at the top.

What's the activated carbon for? We didn't use that.

The students have made important connections in their exploration of the water filter. Now, Ms. Adanya will work with students to connect these ideas to accepted ideas in science.

Resolution

Ms. Adanya asks the community, "What do you know about Flint, Michigan and its challenges with water?"

Is that where they had brown water coming out of the faucet?

The water was dirty. You couldn't drink it.

I think the government or some business did something to the water.

Ms. Adanya fills in the gaps in the student's knowledge with news stories and videos from the local media. After discussing the situation in Flint, Ms. Adanya offers more information about similar problems around the world - the water rights of the Lakota Sioux in the Dakotas, contaminated groundwater in Lowndes County, Alabama, and the limited access to safe, drinkable water in communities around the world. She ends with a discussion using a map of the Chattahoochee River - the main water source in metro-Atlanta - and its challenges related to overuse and pollution. "We've learned a bit about how to clean our water using a water filter. Today, we are going to talk a bit more about how we transport dirty water, clean it, and return it to our homes." Ms. Adanya summarizes the process for transporting water from communities and to the water treatment plant and connects the new information to students' prior knowledge and the ideas developed in earlier lessons. Whenever possible, Ms. Adanya positions herself as a co-investigator and learner as opposed to the one source of knowledge in the classroom.

Application

The next day, Ms. Adanya gathers the class to consider their exploration of water, its value, and the challenges associated with access to clean, freshwater in their communities and around the world. Today, the students will begin to explore how they consume water in their lives. She places a 5 gallon bucket of water on the table in front of her and students immediately connect the bucket to their earlier conversation about the amount of freshwater available to drink on Earth. Ms. Adanya starts with more contextual anchoring by saying, “Take a moment to think about all the ways you use water - how much water do you think you need each day?”

About 8 glasses.

I think I use more than that

How much water is in a bathtub?

Maybe 10 gallons...I think

Ms. Adanya continues, “Most people *need* about 5 gallons of water for everything - drinking, washing, cleaning, and cooking.”

That’s not enough for me.

I probably use that much in the shower.

How much water do you use when you flush the toilet?

Ms. Adanya is inspired by the connections the students are making and the questions they are asking. “Let’s say that you only had 5 gallons of water each day. How would you use it?” As the students share their ideas with partners nearby, Ms. Adanya circulates listening to student conversations and always taking notes. Ms. Adanya gathers the class and says, “We know that there is a limited amount of freshwater for us to use. We also know that it takes a lot of time, energy, and effort to clean water.” She continues, “We should probably pay more attention to how we use water. Let’s try to figure out how much water we use each day. We’ll start by recording all the different ways we use water.”

We drink it.

For showers.

When we go to the bathroom and flush the toilet. (Laughter)

We use it to wash dishes.

Ms. Adanya captures their ideas on the whiteboard. She even adds some of her own ideas. “Now we have a list of all the ways that we use water. If we want to know how much water we use each day, what other information do we need?’

How many times we flush the toilet.

How much water we use when we take a shower.

How do we figure that out?

What about all the water we drink?

Ms. Adanya adds to the discussion. “Scientists and engineers have calculated how much water we use for different things. For example, they know that we use 5 gallons of water each time we flush the toilet.”

That’s all of our water for the day!

In one flush!

Ms. Adanya smiles at the connections being made by the students. She continues, “Scientists and engineers call these flow rates. It’s the amount of water used for an activity. For example, when you wash your clothes in a washing machine, you use about 55 gallons of water each time. I have a sheet of paper with the flow rates for most of the activities on our list. Let’s figure out how much water we use.”

Small groups are given a list of flow rates for different household activities and work together to develop a strategy for calculating the amount of water used for each activity on their list. As they work, Ms. Adanya moves from group to group listening to their discussions, asking guiding questions, and taking notes. Awareness is building.

We use a lot of water.

I'm way over 5 gallons.

I use 6 gallons just to brush my teeth.

I think we are using too much.

Ms. Adanya challenges the class to think about ways that they can reduce the amount of water they use. As the students share their ideas, Ms. Adanya records them on the whiteboard and students engage in discourse with each other about the community's list of strategies. They ask questions, provide explanations, and suggest improvements. Satisfied with their final list, the students decide to share their ideas with others in their homes and communities.

Maybe we should think about how much water we use at school too.

Ms. Adanya had not considered this in the development of her lesson plan. She smiles to herself as she moves to the whiteboard to begin this new list suggested by her class community.

The SCI-Bridge Model

Ms. Adanya's teaching exemplifies our focus on quality science education and on the culturally relevant practices and preparation of teachers working in urban contexts. Urban education itself has focused over time on the policies, practices, frameworks, and scholarship that can improve the experiences and achievement of students living in urban communities (Milner & Lomotey, 2014). Consequently, teacher development programs have sought to support teachers who approach their work and commitment to urban schools through asset-based pedagogies (Aragon, Culpepper, McKee, & Perkins, 2014; Truscott & Stenhouse, 2018). Two such approaches are *culturally relevant teaching/pedagogy* (Ladson-Billings, 1994, 1995, 2009) and *culturally responsive pedagogy* (Gay, 2000, 2010, 2014) center culture in learning. These two pedagogical frameworks have theoretical distinctions, however, as Howard and Rodriguez-Minkoff (2017) assert, the significant overlap in the construction of these frameworks remains nuanced. Similar to the dynamics of urban classrooms, schools and communities, notions of what constitute culturally relevant pedagogy continue to grow (Milner, 2017; McCarty & Lee, 2014; Paris & Alim, 2017). Recognizing this, the SCI-Bridge model presents culturally relevant pedagogy as dynamic, complex, and multidimensional.

The SCI-Bridge model uses the term culturally relevant pedagogy (CRP) as represented in Ladson-Billings' *The Dreamkeepers: Successful Teachers of African American Students* (1995, 2009). She defines culturally relevant pedagogy as "a pedagogy of opposition… specifically committed to collective, not merely individual, empowerment" (p. 160). For Ladson-Billings (1995) "culturally relevant pedagogy rests on three criteria or propositions: (a) Students must experience academic success; (b) students must develop and/or maintain cultural competence; and (c) students must develop a critical consciousness through which they challenge the status quo of the current social order" (p. 160).

Model Dimensions

Figure 1 illustrates the SCI-Bridge model's interconnectivity among its main dimensions and three key CRP practices to create culturally relevant inquiry experiences for children. In developing the visual schematic, we viewed the concentric circles as a reasonable representation of the sophistication of the school context and the actions and reactions of the components.

Gears serve as a visual analogy for considering how the three CRP practices might work in isolation and yet rely on one another eliciting greater force or power resulting from movement.

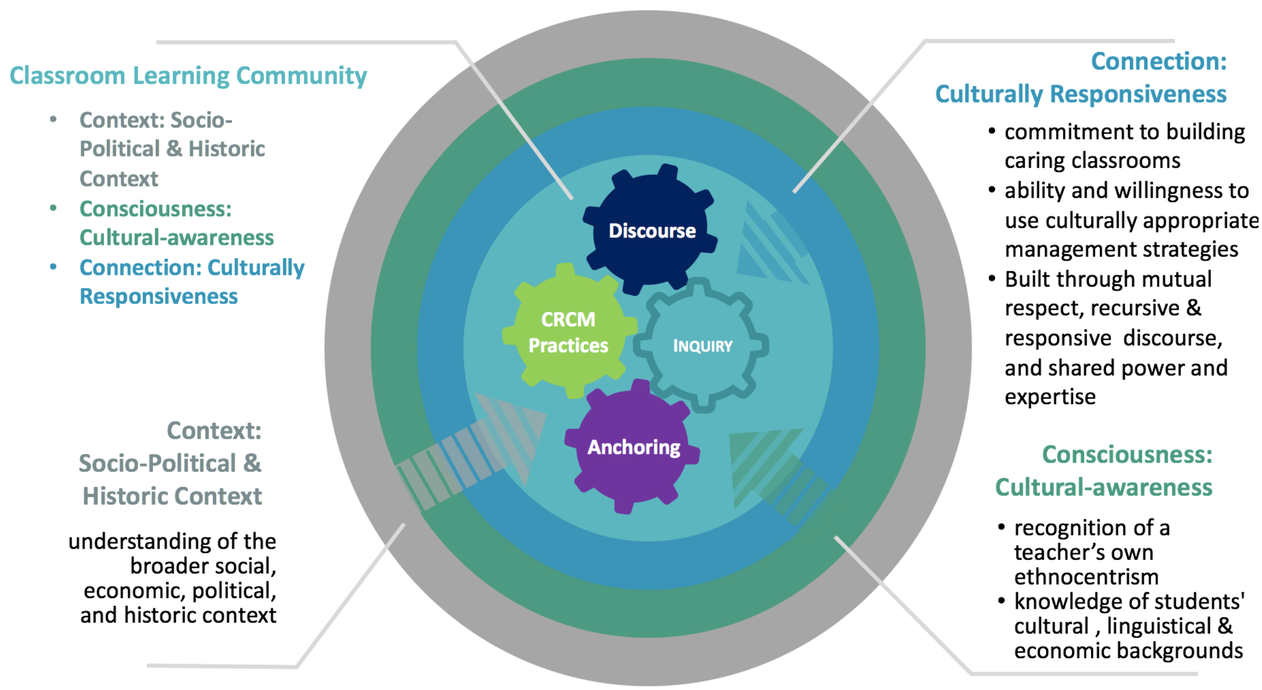

Figure 1

SCI-Bridge Model

The SCI-Bridge Conceptual Model suggests a connection between the educational *context* , the *consciousness* of the members of a community, and the *connections* between individuals in the creation and maintenance of a culturally relevant learning community. The model assumes that these foundational dimensions work in concert to limit or enhance a teacher's ability to effectively implement culturally relevant practices.

Context. The model acknowledges the importance of situating current conditions for teaching and learning within the broader social, economic, political and historical contexts in which they take place. In particular, it places emphasis on “authentically draw[ing] upon and respond[ing] upon the histories, identities, literacies, and language practices of students (Muhammad, 2020, p. 49).

Consciousness. The second model dimension, consciousness, refers to the concept of *conscientização*, the “*development* of the awakening of critical awareness” [emphasis in the original] (Freire, 1974, p.15). Critical consciousness involves entering into dialogue to interrogate and transform oppressive social conditions. It also involves humanizing processes of cultural production. Based on this, the SCI-Bridge model recognizes the crucial role of two related aspects of *conscientização* for teachers' culturally relevant science teaching: (a) teacher's development of ideological and political clarity (Bartolomé, 1994) and (b) their knowledge of students' cultural, linguistic, and economic backgrounds (Gay, 2002).

Connection. In alignment with this, the third dimension in the SCI-Bridge model is connection. Connection involves mutual respect, recursive and responsive discourse, and shared power and expertise. These features focus on connection as a primary goal/principle of caring and relationship-building in classrooms (Jackson, Sealy-Ruiz, & Watson, 2014). Students' perceptions of learning in a caring environment have been found to influence student engagement (Cothran, Kulinna, & Garragy, 2003). Thus, embedded in this dimension is the teacher's ability and willingness to use culturally appropriate management strategies.

The main goal of the model is to support teachers' use of three CRP practices in their work with children; specifically as it applies to inquiry in science education. Effective practices in science education intersect with three CRP practices found to influence the learning of students from low socio-economic, culturally diverse communities (Brown-Jeffy & Cooper, 2011): 1) Contextual anchoring, 2) Facilitated discourse, and 3) Culturally responsive classroom management. These three CRP practices serve as the driving force in the SCI-Bridge model in complex and dynamic ways to support the development of students' academic excellence, cultural competence, and critical consciousness. The practices at the center of the model - contextual anchoring, facilitated discourse, and culturally responsive classroom management - represent examples of CRP. They are not intended to describe the breadth of culturally relevant practices available to teachers in the model. Examples of other practices found in research includes service-learning practices, relationship-building practices, identity-expansion practices (connections between local, national and global communities), cultural congruity practices (learning styles, cooperative learning), among others (Ladson-Billings, 2009; Gay, 2000).

1. **Contextual Anchoring Practices**

Contextual anchoring is rooted in the notion that "we understand something if we see how it is related or connected to other things we know" (Hiebert & Carpenter, 1992, p. 4). Teachers use an anchor to draw on students' knowledge and experiences to contextualize the content being presented and thereby nurture student science learning (Lemons-Smith, 2016). Drawing from sociocultural theory (Vygotsky, 1978), this process of contextualization (Au & Jordan, 1981; Wyatt, 2015) affirms, leverages, and bridges students' funds of knowledge (Moll, Amanti, Neff, & Gonzalez, 1992) and prior knowledge (Marzano, 2004; Orellana, 2001; Paris, 2012; Paris & Ball, 2009).

The SCI-Bridge model emphasizes the use of contextual anchoring to bridge the gap that exists between the materials, content and experiences of traditional approaches and the lived-experiences, communities, cultures, languages, and histories of the students it aims to serve. Traditional approaches to science privilege specific cultural norms that often neglect the diverse array of cultural perspectives and ways of knowing that exist in our world. While CRP is widely regarded as an effective framework for addressing this tension, teachers often struggle to translate it into classroom practices; specifically, as they apply to science. As a result, inquiry-based science instruction can appear culturally irrelevant and disconnected from the experiences of students of color, English language learners, and students from poor communities. Contextual anchoring provides teachers with a well-defined practice that supports culturally relevant approaches to science teaching and learning. This strategy aligns science learning and the cognitive state of the learner throughout the instructional cycle. It presents science content in authentic ways that move beyond inserting cultural artifacts or a child's name into a discussion of a scientific scenario or phenomenon.

2. **Facilitated Discourse Practices**

Critical discourse analysis is a theory that helps explain how language works in society. Its roots date back to the French scholar, Michel Foucault. Foucault proposed that language is not simply words, rather it represents knowledge and power (Rogers, Malancharuvil-Berkes, Mosley, Hui, & Joseph, 2005). These ideas about language are important because they help people think about how discourses contribute to social inequality, and more specifically, about who does and does not have power in society. Scholars such as Chouliaraki and Fairclough (1999), Gee (1999), and Rogers (2004) among others continue to develop theories about language and power. Critical discourse analysts assume that history, power, and context influence the language that individuals use. This means that words are deeper than the surface of the text. Language is rooted in history, laden with power, and influenced by the context in which it is used. Critical discourse analysts also agree that some people are more privileged than others (Rogers et al., 2005).

We position discourse as a theory about how social practices and power dynamics influence language use in society (Gee, 2014; Fairclough, 2010; Foucault). In the SCI-Bridge model, we refer to discourse as the communicative classroom practices in which teachers and students engage. Academically, research supports the need for students to engage in thoughtful discourse that involves explaining and defending students' reasoning in order to build a deep conceptual understanding (Duschl, Osborne, 2002; Hufferd-Ackles, Fuson, & Sherin, 2004; Lampert, 1990; Nathan & Knuth, 2003; Sherin, 2002; Osborne, 2010; Strom, Kemeny, Lehrer, & Forman, 2001). Traditionally, the most common roles for teachers and students in discourse is IRE discourse, which starts with the teacher *initiation (I)* of discourse, followed by student *response (R)*, and then by teacher *evaluation (E)* (Cazden, 2001). This type of discourse typically is implemented between the teacher and an individual student, one student at a time. It is also often characterized by the teacher doing most of the talking, and by a lack of student explanation and defending their science reasoning.

This can be contrasted with more progressive approaches to discourse where teacher talk is reduced and learning is facilitated through more complex student discourse. With this type of discourse, norms change to include students' initiation of discourse topics, as well as the importance of student explanation, defending, questioning, and listening - all vital science practices. Nathan and Knuth (2003) call the IRE/IRF style of verbal exchange *vertical* discourse because of the top-down interaction between the teacher and the students. *Horizontal* discourse, in comparison, is characterized by increased peer-to-peer discourse. Many researchers consider discourse that is *horizontal* in nature to be more productive than *vertical* discourse in developing student conceptual knowledge (Nathan & Knuth, 2003; Sherin, Mendez, & Louis, 2004). The teacher's role in developing a discourse community is in selecting and appropriating worthwhile tasks, clarifying students' reasoning, arguments and justifications, and scaffolding student scientific thinking (Ball, 1996; Brown & Campione, 1994; Jimenez-Aleixandre, Rodriguez and

Duschl, 2000; Sherin, 2002). Discourse communities are also a primary vehicle for teachers and students to learn about each other (communities of practice). It is through dialog that teachers learn about their students in order to implement CRP.

3. Culturally Responsive Classroom Management Practices

Culturally Responsive Classroom Management is a foundational element of quality education and is critical in order to teach science dynamically. In many schools that serve low socioeconomic populations, the goal of classroom management is to have the student silently work independently. This has the potential to interfere with the learning process, which should be rich in discourse and connections. There is a call to make a transformative shift in the understanding and implementation of classroom management, from a traditional, teacher-centered understanding built through years of *apprenticeship of observation* (Lortie, 1975) to an understanding of classroom management as complex, multifaceted, and student centered (Elias & Schwab, 2014; Freiberg & Lamb, 2009; McCaslin. & Good, 1998). Evertson and Weinstein (2006) defined classroom management as “the actions teachers take to create an environment that supports and facilitates both academic and social-emotional learning” (p. 4). In order for teachers to implement inquiry-based science activities that elevate student-centered discourse communities and hands-on science learning, teachers must implement classroom management techniques that both bring order and at the same time allow student autonomy and voice. One approach that shows promise is Weinstein, Tomlinson-Clarke & Curran’s (2004) culturally responsive classroom management (CRCM). Weinstein et al. (2004) state that teachers who implement CRCM must: (a) recognize their own ethnocentrism; (b) have knowledge of their students’ cultures; (c) understand of the broader social, economic, and political systems in education; (d) use appropriate management strategies; and (e) develop a caring classroom. This approach takes a proactive stance where developing a fertile classroom community where power is shared, voice is elevated and identity as a valued member is essential. This approach relies on developing rituals and routines and is proposed as central to the SCI-Bridge model.

Application of the SCI-Bridge Model in Science

Application of the SCI-Bridge model adapts Bybee's (2009) 5E model as a means of structuring inquiry in the CRP science classroom (see Figure 2). Unlike the 5E's, which are traditionally applied solely to science instruction, the SCI-Bridge model is intended to be used across the curriculum. This design decision is aligned with the idea that, in order to be effective, CRP must be integrated across the scope of a teacher's practices..

Application of the SCI-Bridge model borrows heavily from the core assumptions of Bybee's framework including appreciating students are agents of their own learning, acknowledging teachers and students as co-investigators and co-constructors of knowledge, building opportunities to learn through experience, and enhancing student understanding through application to new contexts. One major difference between the SCI-Bridge model and the Bybee's 5E's is the integration of the fifth stage of evaluation into the other four stages of the model. This is in alignment with later iterations for Bybee's 5E model.

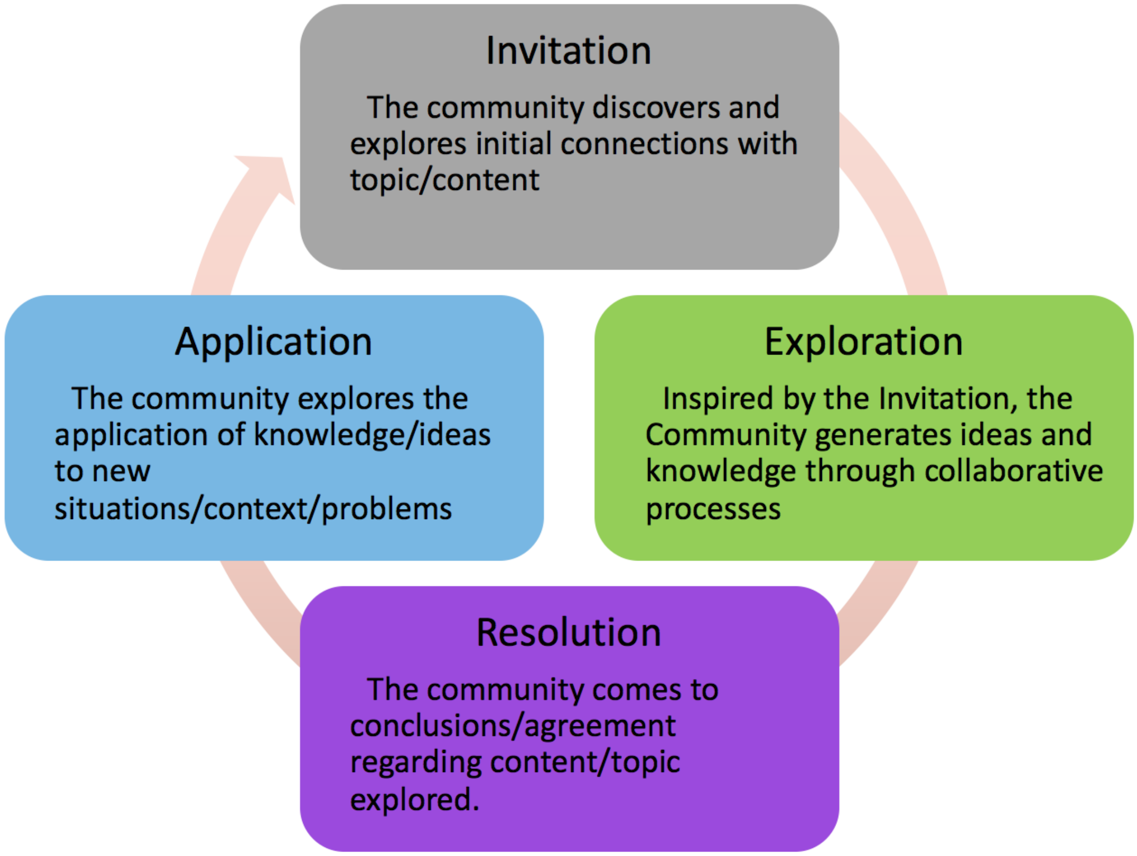

Figure 2

SCI-Bridge Instructional Framework

A SCI-Bridge lesson begins with an **invitation.** Traditionally in this stage, students are invited to the lesson and the content is introduced. In the SCI-Bridge model, a classroom community meeting provides the context for the lesson invitation using CRCM techniques (e.g., morning meeting, circle time…). In the classroom community meeting, essential and critical questions prompt facilitated discourse and conversation among the community members and thereby provides a shift from IRE discussion patterns to more exchange among group participants. These important invitation questions should inspire curiosity of content to be explored but also activate prior knowledge rooted in student identity including alternative conceptions. Contextual anchoring in this way is more than activating background knowledge. It sets the stage for (1) connecting content with the context of the larger world, (2) strengthening connections between members of the community, and (3) nurturing critical consciousness regarding the self, the other, and the content being explored by focusing on the content to be learned with the students' lived experiences, culture, and history front and center. The glimpse provided at the beginning of this paper shows how Ms. Adanya achieves this invitation to a new science unit on water with a simple question *"Where in the world is our clean, fresh water?"*

Exploration is key to inquiry-based science learning and represents the next stage in the model. In this stage, students explore the questions or problems presented in the invitation stage. This exploration should provide students with an opportunity to construct some understanding of the content being presented in the lesson through guided investigation. Facilitated discourse during this stage focuses on sense-making. Consequently, the teacher does not provide direct instruction. Instead, teachers and students work as co-investigators. Together, they pose real questions, develop hypotheses, design investigations, collect data, and make arguments related to the content being explored. Important to the SC-Bridge model is the balance between structures the teacher provides and the freedom for students to construct ideas through the exploration of phenomena utilizing scientific practices such as discourse and leveraging historical and cultural knowledge and lived experiences. These structures can take many forms including the use of children's literature, digital media, role plays, discrepant events, presentation of a phenomenon, and other strategies. Ms. Adanya's new guiding question to the class *"If this is all the freshwater we have to drink, how do we clean the water that we use...what happens to the water that you drain from the bathtub ...that goes down the sink after you wash the dishes…"* sparked exploration of the topic through drawing, peer-led discussion and questioning, teacher demonstration, and small group investigations to design water filters.

Building from the small group investigations, Ms. Adanya entered into the next stage of the model, **resolution,** by helping students develop and make connections between their constructed understandings and accepted scientific knowledge. This includes defining vocabulary and refining student conceptions. Facilitated discourse during this stage encourages students to articulate, defend, and refine their understanding of the content being explored. Contextual anchoring continues. Ms. Adanya continues to build connections between concepts being articulated by the students and their historical and cultural knowledge and lived experiences through this challenge *"We should probably pay more attention to how we use water. Let's try to figure out how much water we use each day. We'll start by recording all the different ways we use water."* Context, connection and consciousness permeate a SCI-Bridge lesson.

Because the ideas constructed in the exploration and resolution stages focus on a single phenomenon, students strengthen their understanding of the content by applying it to a new and different context. During the **application** stage, students refine the ideas by posing questions, developing hypotheses, designing investigations, collecting data, and making arguments related to the new context together. The importance of taking responsibility for one's learning and contributing as a member of the learning community results in the creation of new knowledge and envisionment of identities connected to science. In Ms. Ayana's lessons, she does not conclude the work the class has done on the topic of water, and instead, propels new investigations (which lead to more invitations) by asking the students to explore how they consume water in their lives. Students step forward and take the lead and apply to new contexts by asking "*Maybe we should think about how much water we use at school too."*

Implications

High poverty, racially and ethnically diverse schools (e.g., Title I schools) need effective new teachers. Understanding the complexities of teaching requires that "…new teachers need to learn situationally relevant approaches to subject matter" (Feiman-Nemser, 2003, p. 2). Sixty percent of K-12 students in the state in which we practice live in low-income households, while 55% of children under the age of eight are living at 200% below the poverty level. Economic disadvantage is directly related to disparity in student achievement, and in this 10-county metropolitan region, the achievement gap is calculated at 38% (masked source, 2014). The interplay resulting from layers of racial, linguistic, cultural, economic, and linguistic diversity is so salient to teacher effectiveness and student achievement that it constitutes a demographic imperative.

Opportunities to learn science in schools depends on a number of distinct factors including the quality of the curriculum and instructional staff; the availability and use of appropriate materials; facilities; expectations of teachers, parents, and students; and the attitudes of parents, peers, and community (Darden & Cavendish, 2011; Museus, Palmer, Davis, & Maramba, 2011). Starting in 2011, the State Department of Education, in an effort to prepare its students for workplace careers began awarding STEM certification to schools that meet state requirements including the integration of curriculum that is driven by exploratory project-based learning and student-centered development of ideas and solutions. As a part of this effort, we assisted two partner schools in their successful bid to become STEM Certified elementary schools. The school district we worked with provided a vision and the means to help schools build the infrastructure and foster the teaching dispositions needed to change STEM learning. After great effort by the school administration and teachers at developing and delivering quality STEM learning curriculum and experiences, it was noted that science scores dropped or stayed constant on the state assessment. Upon further investigation, this trend held true across school districts, but only for high-poverty, ethnically-diverse Title I schools, whereas Non-Title I schools realized an increase in their students' science scores. This phenomenon appears discipline specific in that while STEM certification did not positively impact Title I schools in science, it did in mathematics. All schools seem to benefit in math from STEM certification. In fact, Title I STEM schools seem to benefit in math more than non-title 1 STEM schools do.

What adds to this perplexing outcome is that science learning often takes a backseat to the learning of reading and math in Title I urban schools (Market Research Institute, 2004; McMurrer, 2008) and so it was thought that an intense focus on STEM education should lead to increased scores in science. This prompted us to question whether the STEM learning experience in these Title I schools were responsive to the students it was meant to serve. What we have come to learn is that providing a curriculum infrastructure and a school-wide vision is not enough to transform instruction and impact teaching practices and student achievement in Title I STEM schools. The *SCI-Bridge* model changes the conversation about broadening participation of economically, culturally, and linguistically diverse student populations by committing to a process in which funds of knowledge can be tapped, integrated, and propelled. Purposeful pedagogical moves (facilitated discourse & contextual anchoring) in well-structured responsive classrooms (CRCM) such as those displayed by Ms. Adanya address challenges with broadening participation in science and inequities in access to quality science instruction found in elementary schools. While we examine how the model can be implemented in inquiry-based lessons in the science classroom, we are hopeful that it has the potential for application across the curriculum.

Author Note

The SCI-Bridge model is supported, in part, by a grant funded by the National Science Foundation: DRK-12 #2010361. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the SCI-Bridge Project and do not necessarily reflect the views of the National Science Foundation.

References

Aragon, A., Culpepper, S. A., McKee, M. W., & Perkins, M. (2014). Understanding profiles of preservice teachers with different levels of commitment to teaching in urban schools. *Urban Education*, *49*, 543- 573.

Au, K. H., & Jordan, C. (1981). Teaching reading to Hawaiian children: Finding a culturally appropriate solution. In H. Trueba, G. P. Guthrie, & K. H. Au (Eds.), *Culture in the bilingual classroom: Studies in classroom ethnography* (pp. 140–162). Rowley, MA: Newbury House.

Brown, A. L., & Campione, J. C. (1994). Guided discovery in a community of learners. In K.McGilly (Ed.), *Classroom lessons: Integrating cognitive theory and classroom practice* (pp. 229-270). Cambridge, MA: MIT Press/Bradford Books.

Brown-Jeffy, S., & Cooper, J. E. (2011). Toward a conceptual framework of culturally relevant pedagogy: An overview of the conceptual and theoretical literature. *Teacher Education Quarterly*, *38*(1), 65-84.

Cazden, C. B. (2001). *Classroom discourse: The language of teaching and learning*. Portsmouth, NH: Heinemann.

Cothran, D. J., Kulinna, P. H., & Garrahy, D. A. (2003). “This is kind of giving a secret away...”: students’ perspectives on effective class management. *Teaching and Teacher Educa-tion*, *19*(4), 435-444.

Darden, E. C., & Cavendish, E. (2011). Achieving resource equity within a single school district: Erasing the opportunity gap by examining school board decisions. *Education and Urban Society, 44*(1), 61–82.

Duschl, R. A., & Osborne, J. (2002). Supporting and promoting argumentation discourse in science education. *Studies in Science Education*, 38(1), 39-72.

Feiman-Nemser, S. (2003). What new teachers need to learn. *Educational Leadership, 60*(8), 25-29.

Freiberg, H. J., & Lamb, S. M. (2009). Dimensions of person-centered classroom management. *Theory into practice*, *48*(2), 99-105.

Gay, G. (2000). *Culturally responsive teaching: Theory, research, and practice*. New York, NY: Teachers College Press.

Gay, G. (2010). *Culturally responsive teaching: Theory, research, and practice* (2nd ed.). New York, NY: Teachers College Press.

Gay, G. (2014). Culturally responsive teaching principles, practices, and effects. In H. R. Milner IV & K. Lomotey (Eds.), *Handbook of Urban Education*, (pp. 353- 372). NY: Routledge.

Hiebert, J., & Carpenter, T.P. (1992). Learning and teaching with understanding. In: D. A. Grouns (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 65-92). New York: Macmillan.

Howard, T. C., & Rodriguez-Minkoff, A. C. (2017). Culturally relevant pedagogy 20 years later: Progress or pontificating? What have we learned, and where do we go? *Teachers College Record*, *119*(1), 1- 32.

Hufferd-Ackles, K., Fuson, K. C., & Sherin, M. G. (2004). Describing levels and components of a math-talk learning community. *Journal for Research in Mathematics Education*, *35*(2),81-116.

Jackson, I., Sealey-Ruiz, Y., & Watson, W. (2014). Reciprocal love: Mentoring Black and Latino males through an ethos of care. *Urban Education*, *49*(4), 394-417.

Jiménez-Aleixandre, M. P., Rodríguez, A. B., & Duschl, R. A. (2000). “Doing the lesson” or “Doing science”: Argument in high school genetics. *Science Education, 84,* 757-792.

Ladson-Billings, G.(1994, 2009). *The dreamkeepers: Successful teachers of African-American children*. San Francisco, CA: Jossey-Bass.

Ladson-Billings, G. (1995). But that’s just good teaching! The case for culturally relevant pedagogy. *Theory into Practice*, *34*, 159-165.

Lemons-Smith, S. (2016). Contextual Anchoring + Math = Equity. *Georgia National Association of Multicultural Education: What’s the Idea? 4*(2), 9-10.

Lortie, D. C., & Clement, D. (1975). *Schoolteacher: A sociological study* (Vol. 21). Chicago: University of Chicago Press.

Market Research Institute. (2004). *The Bayer facts of science education X: Are the nation’s colleges and universities adequately preparing elementary schoolteachers of tomorrow to teach science?* Mission, KS: Author.

Marzano, R. J. (2004). *Building background knowledge for academic achievement: Research on what works in schools*. Alexandria, VA: Association for Supervision and Curriculum Development.

McCaslin, M. & Good, T. L. (1998). Moving beyond management as sheer compliance: Helping students to develop goal coordination strategies. *Educational Horizons*, *76*(4), 169-76.

McMurrer, J. (2008). *Instructional time in elementary schools: A closer look at changes for specific subjects*. Washington, DC: Center on Educational Policy.

Milner IV, H. R. & Lomotey, K. (2014). Introduction. In H. Richard Milner IV & K. Lomotey (Eds.), *Handbook of urban education* (pp.xv-xxiii). NewYork, NY: Routledge.

Mindich, D., & Lieberman, A. (2012). *Building a learning community: A tale of two schools.* Stanford, CA. Stanford Center for Opportunity Policy in Teacher education.

Moll, L. C., Amanti, C., Neff, D., & Gonzalez, N. (1992). Funds of knowledge for teaching: Using a qualitative approach to connect homes to classrooms. *Theory into Practice*, 31, 132–141.

Museus, S., Palmer, R. T., Davis, R. J., & Maramba, D. C. (2011) *Racial and ethnic minority students' success in STEM education*. Hoboken, NJ: Jossey-Bass.

Nathan, M. J., & Knuth, E. J. (2003). A study of whole classroom mathematical discourse and teacher change. *Cognition and Instruction, 21*(2), 175-207.

Orellana, M. F. (2001). The work kids do: Mexican and Central American immigrant children's contributions to households and schools in California. *Harvard Educational Review*, 71(3), 366–390.

Paris, D. (2012). Culturally sustaining pedagogy: A needed change in stance, terminology, and practice. Educational Researcher, 41(3), 93–97.

Paris, D., & Ball, A. (2009). Teacher knowledge in culturally and linguistically complex classrooms: Lessons from the golden age and beyond. In L. M. Morrow, R. Rueda, & D. Lapp (Eds.), *Handbook of research on literacy instruction: Issues of diversity, policy, and equity*. New York, NY: Guilford.

Osborne, J. (2010). Arguing to learn in science: The role of collaborative, critical discourse. *Science*, *328*(5977), 463-466.

Sherin, M.G., Mendez, E.P., & Louis, D.A. (2004). A discipline apart: The challenges of fostering a community of learners' in a mathematics classroom. *Journal of Curriculum Studies, 36*(2), 207-232.

Sherin, M.G. (2002). When teaching becomes learning. *Cognition and Instruction, 20*(2), *119-150.*

Truscott, D. & Stenhouse, V. (2018). A mixed methods study of teacher dispositions and culturally responsive pedagogy. *Urban Education* https://doi.org/10.1177/0042085918801438

Weinstein, C. S., Tomlinson-Clarke, S., & Curran, M. (2004). Toward a conception of culturally responsive classroom management. *Journal of Teacher Education*, *55*(1), 25-38.

Wyatt, T. (2015). Understanding the process of contextualization. Multicultural Learning and Teaching, 10(1), 111-132. doi:http://dx.doi.org/10.1515/mlt-2013-0026