C²AST (Critical and Cultural Approaches to Ambitious Science Teaching)

From Responsive Teaching Toward Developing Culturally and Linguistically Sustaining Science Teaching Practices

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Educators must consider how K–12 science can be transformed to provide a vision of hope and educational justice. The global pandemic has exacerbated deep racial and economic inequities in our society and highlighted the importance of having a scientifically informed public. Science educators need to intentionally focus on social and restorative justice. We must acknowledge and address the injustices that plague our schools and society and that have marginalized groups of students, families, and communities for multiple generations. It is unacceptable to continue teaching science with a "sterile," one-size-fits-all approach that continues to perpetuate injustices by ignoring the voices, needs, experiences, and thus humanity of a significant number of students.

Focusing on social and restorative justice means we must challenge current notions and enactments of culturally responsive science teaching that focus on deepening engagement and broadening participation for culturally and linguistically minoritized students. These approaches are necessary but insufficient as we also need a critical perspective to address historical wrongs in science and school and to move beyond a conceptualization of equity as simply issues of access, opportunity, and achievement (Calabrese Barton and Tan 2020). This means interrogating the notion that while European science has made many advances, Black, Indigenous, and people of color (BIPOC) have been actively harmed in doing so and scientific industries and school systems have failed to uplift science done by and for BIPOC. Importantly, this science contributes diverse perspectives of hope and possibilities and helps sustain communities of color. Beyond addressing the moral and ethical demands of righting current and historic wrongs, a socially just approach to science education fosters the production of stronger science learning and ultimately stronger science through the integration of truly diverse questions, approaches, and resources. With a broadened view of the discipline and how scientific knowledge has been and could be constructed, educators can reshape a new science that sustains non-dominant community cultures and ways of being, creating a pluralistic society (Paris and Alim 2014).

We propose a four-part framework for *Critical and Cultural approaches to Ambitious Science Teaching, C²AST,* to support educators in grounding learning opportunities in students' cultures and identities and work toward culturally and linguistically sustaining practices. We build on our previous work with Ambitious Science Teaching, which emphasizes valuing students' ideas and anchoring science units in real-world phenomena (Windschitl, Thompson and Braaten 2018), and offer a critical equity perspective for teachers to consider issues of power, identity, and the sociopolitical context (Gutiérrez 2002). For each principle, we begin with a vignette, unpack central ideas, and suggest culturally and linguistically sustaining tips as starting places for science educators.

Principle 1: Recognizing our own and other's worlds and developing critical consciousness

Ms. Colley raised a blow-horn in the middle of a playfield as students and other teachers stood at different distances ready to record decibels. Everyone paused as an airplane flew over and landed at a nearby airport. One student exclaimed, "I hate airplanes. They wake me up every night." Other students chimed in with stories of not sleeping and walls rattling. As teachers, we met after class and decided that the overarching puzzling phenomenon about a singer shattering a wine glass with his voice was insufficient. We researched city ordinances and discovered they were 25 years old and decided to develop a complementary literacy unit to support students in writing to city and airport officials about the realities of sound pollution. Yet, many of us did not confront our own privilege as we drove home to a quieter part of town.

While the teachers responsively took up a problem that students raised, we needed to do more to examine our own positionality, issues of power, and privilege prior to action. Upon reflection, we offer these suggestions to heighten teacher awareness: When students use passionate language (e.g., I hate airplanes.), pause and ask: How can I learn more about my students' experiences? How can I be responsive to my students' context? If I am experiencing cognitive dissonance (e.g., I don't feel as strongly as my students), ask: How can I check my own assumptions and examine how my privilege and power are a part of this situation?

The first principle in the C²AST framework addresses critical consciousness as an understanding of one's own positionality and biases. Because many teachers grew up learning science in unjust and racialized contexts and have not been positioned to question these perspectives, teachers need experiences that challenge eurocentrism so they can shape new visions of teaching and learning science that will be more inclusive of students' rich linguistic, racial, and cultural resources. *Tip 1: Find critical colleagues.* Start a book club and read critical literature (i.e., DiAngelo's *White Fragility* (2018), Kendi's *How To Be An Antiracist* (2019), or *So You Want To Talk About Race* by Oluo (2019), and Abolitionist Teaching Network https://abolitionistteachingnetwork.org/), and brainstorm how to decenter whiteness in upcoming lessons. Examine the culture of power (Delpit 1988), the socio-historical context and how it shapes school and science learning (Bang et al. 2012), the importance of moving beyond equity as inclusion (Calabrese Barton and Tan 2020), and the typical "equity detours" (Gorski 2019).

Simultaneously, engage in self-reflection to understand one's own narratives about race, class, language, and culture and question the dominant narratives that are often portrayed in science learning. *Tip 2: Write a K–12 autobiography.* Reflect on the ways in which you experienced continuity (or not) among home and school and write a self-narrative about cultural and linguistic (dis)connection, identity, access, and power in school science (Costa 1995; Phelan, Davidson, and Cao 1991). Frequently revisiting these narratives, in light of experiences in classrooms and additional readings, can help broaden one's perspective about privilege, power, and students' capabilities (Villegas and Lucas 2007).

Principle 2: Learning about and prioritizing students' communities and cultures

Youth, seasonal farm workers, school board members, and other community stakeholders worked with teachers to brainstorm questions and problems that matter to their rural hometown. In the midst of the conversation, one youth asked, "Why do grocery store strawberries taste chemically?" She explained that the fruit from the store doesn't taste the same as what they grow. Pursuing this question, a teacher called an organizer at a local farmers market,

which led to a summer of collaboration among farmers, teachers, youth, and community members. They designed a weeklong summer camp where youth engaged in farming, selective breeding, soil sampling, and analysis in the different fields of their community partner. Situating science in the community in which students lived served to invite youth to share related ideas from their life experiences, resulting in the shaping of the why, where, and how their science work was done. At the culmination of the camp, youth presented their work and findings to their community and others whose recognition mattered to them—family, local press, university people (See Figure 1). Youth ultimately described a renewed sense of appreciation for the food they ate and a town they thought they couldn't wait to get out of.

Though the science curriculum focused on soil composition and testing, the phenomenon driving the study was a student's question. Situating the science in a local issue prioritized places, people, and languages that were familiar to youth. Moreover, youth developed positive science identities as they participated in and were recognized by themselves and others as science doers and thinkers.

The second principle of the C²AST framework intentionally situates science learning in service of the plurality of youths' cultural identities. Cultural membership is different for each person; teachers have a responsibility to seek to understand what various cultural memberships mean for particular students. Knowing what is valued in a community offers a lens into and connections with local culture. *Tip 1. Create an asset map of local resources* related to the upcoming units you are teaching (see Figure 2). The map can include physical assets such as buildings, economic assets such as beauty shops, institutional assets such as churches, and human assets including stories from newspapers or grandparents. Consider constructing this map with community-based organizations or parents. Beyond connecting to these assets, science education can serve to positively influence and intentionally sustain aspects of local culture by positioning students as people who can immediately use their knowledge learning to inform or celebrate local ways of knowing or doing. *Tip 2. Do a community needs assessment.* Listening to and learning from community stakeholders can reveal problems that provide an authentic need and audience for science learning. Yet, not all aspects of students' cultures are healthy. The youth from the vignette developed a tradition of drinking water from a nearby drainage ditch before sporting events. Teachers invited youth to use science to critique local culture, using water quality findings to justify a needed change in practice. *Tip 3. Include critical conversations as a core of classroom culture.* Include topics in your classes that help students examine their own and other's experiences (i.e., with vaccines or access to clean water) and the ways in which stakeholders have failed to consider multiple perspectives.

FIGURE 1

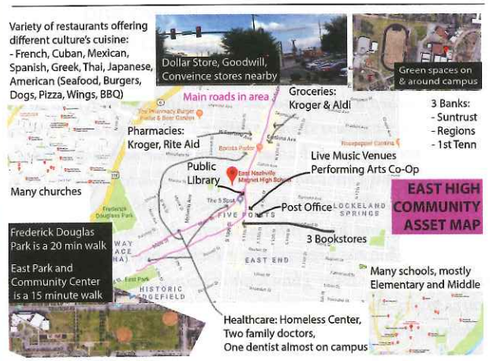
Campers from five different science lab teams presented their scientific work, findings and community outreach efforts to an audience of teachers, families, community partners, school administrators and local and regional press. The scientific studies of the Loyal to Soil campers brought positive publicity to the local farmers market.

Principle 3: Designing for each student's full participation in the culture of science

"We are a group of ladies taking a stand for the lake next door. We are investigating the health of Hicklin Lake and hope to get others involved. In the 1960s it was a swimming hole. Over the years it has become a dump and the lake has become eutrophic. We want to clean it for others and animals to enjoy it." A group of middle and high school young women participating in an after-school program used these words to open their film to raise awareness about a toxic lake by their school. For months they conducted experiments, interviewed community members and scientists, revised working models of the biochemical processes, and developed a film. They opted to use stop-animation as a youth-friendly way to tell the story of how the lake becomes toxic each spring and is dangerous for domestic animals and wildlife, and how scientists and community members are trying to revive the lake using islands with floating plants to remove excess phosphorus. The film closed with the young women talking in their home languages (Spanish, Arabic, and Somali) to family and community members about what they learned about themselves. Film: https://vimeo.com/92776664

FIGURE 2

Community asset map identifying physical, natural, institutional, and economic assets around one school community.



These young women fully participated in science as they enacted their multiple identities as scientists, activists, and family members and sought to take action in their own community (Luehmann 2016). Developing the film allowed them to share their research using their languages, identities, and local experiences as sensemaking repertoires.

The third principle in the C²AST framework entails creating opportunities for students to fully participate in school science in ways that honor and leverage cultural and linguistic identities and sensemaking practices. Phenomenon-based learning, such as investigating how to clean up a toxic lake next to the school, allows students and teachers to interact directly with the natural world and invites collaborative and diverse sensemaking. *Tip 1: Involve students in the design of phenomenon-based curriculum and co-create shared experiences in the classroom.* Involving students in the design of the unit and open-ended investigations into real-world phenomena (such as designing experiments with lake water samples and creating a stop-animation film) shifts power structures in the classroom and creates opportunities for students to share their expertise and learn from others.

Designing for students to fully participate in scientific sensemaking also requires that teachers center students' multilingual and multi-literate ways of knowing. Research in the workspaces of scientists shows that they use multiple languages, gestures, and narrative language to communicate ideas.

Designing for students to fully participate in scientific sensemaking also requires that teachers center students' multilingual and multi-literate ways of knowing. Research in the workspaces of scientists shows that they use multiple languages, gestures, and narrative language to communicate ideas. *Tip 2: Privilege students' broad sensemaking repertoires.* Invite students to use translanguaging (Suárez 2018) as productive sensemaking in classrooms; challenge students to think about how they use language in science; and avoid front-loading vocabulary, which sends the message that there is "a right way" to use language in science classrooms (Suárez et al. 2019). Along with this shift in pedagogy, teachers can challenge their own perceptions of how science should look and sound, and strive to unlearn ideologies that are Eurocentric and monolithic.

FIGURES 3 AND 4

Images from STARS (Students Tackling Authentic and Relevant Science) stop-animation film and prototypes of signs the young women developed to inform the public.

FIGURE 5

An equity noticing tool for examining students' scientific ideas inspired by Patterson Williams, Higgs and Athanases 2019.

Science Knowledge Matters. Students' ideas are scientific. What do students already understand about the phenomenon?	**Language & Expression of Ideas Matters.** What everyday language did students use? How did students use multiple languages or different narrative forms? How were they representing key ideas without words (i.e., gestures, use of color in work)?
Race, Power and Justice Matter. How are students showing/writing about race, power and justice (including justice for animals and the environment)? How did students talk about their own agency, such as how they can/will take action in the world?	**Histories, Realities and Futures matter.** What lived experiences did students draw on? What did you learn about their possible interests and identities (now or in the future)?

Interrogating one's principles and practice requires opportunities for reflection and the development of "interpretive power" to understand students' language use, gestures, manipulation of materials, and interactions with peers. *Tip 3: Use video and student work to reflect on classroom interactions.* Examining video with frameworks that attend to race, language, justice, and history (Patterson Williams, Higgs, and Athanases 2019) challenges teachers to recognize that students are always making sense and to identify how classroom interactions are part of larger social narratives.

Principle 4: Challenging the culture of science through social and restorative justice

In high school Biology, students modeled HeLa cells and how cervical cancer cells continuously divide. Simultaneously, for Language Arts they read Rebecca Skloot's The Immortal Life of Henrietta Lacks *and wrote evidence-based claims about the bioethical issue of scientists taking cells without consent. They read legal codes, discussed injustices, and studied how Lacks' family fought to raise awareness. On a culminating assignment, one student reflected, "Although scientists have made many breakthroughs with her cells, they don't give much importance to the woman who provided them the key to their research. It is surprising the family has not been given anything for their mother's cells despite the fact that they did not give permission to take the cells. The court has given scientists the right to exploit a patient's tissue for their economic benefit and failed to recognize where the tissue came from. I can't imagine the mixture of feelings the family must have, their mother's cells changed history."*

TABLE 1

Critical questions to support self-assessment and planning.

C²AST Principle	Self-Assessment	Planning
Principle 1 Recognizing our own and other's worlds and developing critical consciousness	How am I privileged? How do I participate in the culture of power?	Whose knowledge is valued in the classroom/learning space? What kind of science identities do I want to promote and reinforce?
Principle 2 Learning about and prioritizing students' communities and cultures	How do I attend to, leverage, and sustain language, race, and culture when designing engaging and inclusive curriculum with historically marginalized students?	How can I build bridges between multiple cultures represented in my school community?
Principle 3 Designing for each student's full participation in the culture of science	What does it look and sound like when students bring broad sensemaking repertoires and practices that leverage their whole selves and ways of knowing into the science classroom?	How do I design my lessons, classroom activities, assessments, and norms to make space for expansive science sense making?
Principle 4 Challenging the culture of science through social and restorative justice	How do I question my own harmful narratives about racial injustice and bias in science and science classrooms?	How can I create emotionally and intellectually safe spaces for students to question racial injustice in science and science classrooms? How can I support social and restorative justice?

The teachers provided students with the opportunity to analyze the harmful impact of bias and injustice, engage in conversation about actions that would repair this harm, and examine institutional injustices. Yet they did so in a way that emphasized stories of empowerment and justice, not damage and deficit-centered narratives. Engaging students in these conversations provides opportunities for students to critique and challenge the culture of science and work collaboratively to create change.

The fourth principle of the C²AST framework recognizes that social justice calls for prejudice reduction and collective action (Teaching Tolerance 2016). Students need to question and challenge myths about "science as truth," critique European science as a dominant way of knowing and engage a heterogeneity of ideas and multiple ways of knowing. *Tip 1: Analyze classroom culture.* Invite students to examine the culture of the science classroom, cultural (dis)connections, and ask about experiencing marginalization. Teachers can support students in this challenging work by using Color Brave Safe Principles (Schillinger and Okuno 2017) to attend to racial equity and the concept of Intellectual Safety (Jackson 2001) to cultivate collaborative civic spaces (Makaiau 2015). This will help students feel emotionally and intellectually secure to ask questions and state multiple and sometimes opposing views. What develops out of this is trust, the courage to present one's own thoughts, and opportunities to practice democracy.

Principles from restorative justice—the idea that we must create just and equitable learning environments, avoid punishments, nurture healthy relationships, repair harm, and transform conflict (Winn 2018)—can address the disenfranchisement of students. *Tip 2: Learn about talk circles.* Read about and implement talk circles as a way to address serious classroom matters, including conversations about harms and injustices (Bintliff 2014).

As products of unjust school systems, injustices as well as stories of bravery can be difficult to see. *Tip 3: Get involved.* Participate in community-based civic engagement activities and read about social justice projects. Identify the knowledge, inquiry skills, and dispositions needed to promote justice.

Conclusion

As science classrooms are becoming increasingly diverse—linguistically, racially, and socioeconomically—science instruction needs to support the honoring and continued strengthening of students' varied identities (NRC 2012). We have found it useful to approach the discipline with humility toward the relative im-

portance of scientific achievements; as such science teachers can nurture the plurality, diversity, and generative nature of culture that is both beautiful and necessary for global citizenship. Our hope is that the C²AST framework offers a starting place for educators to create learning environments that develop students' identities as learners, scientists, and publicly engaged citizens. We encourage teachers to develop professional learning communities and use the framework, resources, and self-assessment and planning questions (see Table 1) to get started on this critical work. Our sense is that self-assessment and planning are reciprocal processes and that teachers will return to self-assessment during the planning process and after teaching. ■

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