

Culturally Responsive and Sustaining STEM Curriculum as a Problem-Based Science Approach to Supporting Student Achievement for Black and Latinx Students

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This article explores the tenets of culturally responsive STEM curriculum, providing an innovative look into STEM teaching and learning, which illuminates student agency, prior knowledge, and positive connections with their teachers. It seeks to answer the question, what happens when students experience informal STEM learning spaces as positive ones that enable them to develop a sense of agency, voice, and academic achievement.

“To teach in a manner that respects and cares for the souls of our students is essential if we are to provide the necessary conditions where learning can most deeply and intimately begin...” — bell hooks

Four distinct problems cause many Black and Latinx students to lack persistence and success in STEM and therefore call for a new curricular approach to STEM education: 1. Black and Latinx students enter into secondary STEM learning spaces with gaps in knowledge; 2. Black and Latinx students lack early exposure to STEM education; 3. The students’ existing funds of knowledge of STEM concepts are not often acknowledged or utilized in the classroom; and 4. Students lack a connection to their experiences and the STEM content, thereby stunting their academic identity.

Researchers have uncovered many reasons as to why Black and Latinx students do not persist in STEM. Perna et al. (2009) attribute the barriers to STEM success to “inadequate academic preparation by elementary and secondary schools, inefficient attention to the psychological barriers that limit persistence in STEM fields, and inadequate support by colleges and universities” (pp. 2-4). The lack of success in STEM and the perceived declining persistence in STEM for Black and Latinx students is attributed to the social barriers they face within their academic environments, or the lack of preparation they received prior to entering the STEM program.

Research also suggests that Black and Latinx students do not perform well

in science classrooms or perform well on assessments focused on the epistemological basis of knowledge construction of science and indigenous science. Cajete (1988) describes indigenous science as one where “the American Indian students possess a cultural worldview that is significantly different from that of American society at large. This, in turn, affects students’ perceptions and receptivity to science and math” (p. 2). Alternatively, Snively & Corsiglia (2001) describes Western modern science as that which is adopted by “science educators who have long assumed that only Western modern scientific knowledge was true knowledge” (p. 24). Still, further, Aikenhead & Ogawa (2007) view science practiced by Native American students as conflicting with Western modern science, and as a result, science teachers (as well as teachers trained in the computer science, engineering, and mathematics disciplines) often may not acknowledge the funds of scientific knowledge possessed by those students, thus rendering this knowledge as invalid scientific knowledge.

To address this gap in curricular solutions, I argue that there exists a need to address the lack of student early exposure to STEM and the way that computer science, science, and engineering are taught in the classroom so that more students can

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realize success in STEM and thrive in those learning spaces.

To address this gap in curricular solutions informed by research, I designed a curriculum that engages with students in order for them to realize success in STEM. This new curricular approach presents opportunities for students to bring their culture and prior funds of knowledge into the classroom in order to bridge it with STEM content. How might doing things differently, in terms of utilizing the prior knowledge, cultural experiences, and the established or emerging achievements of Black and Latinx students within PreK-12 learning spaces enhance STEM knowledge acquisition?

Background and Conceptual Framework: The Case for a More Culturally Responsive and Sustaining STEM Curriculum

What is needed in classrooms, particularly urban classrooms is a culturally responsive STEM curriculum that is both an explicit

and implicit curriculum and recognizes that different kinds of cultures exist within the classroom and that culture is not just a construct derived from ethnicity or nationalism. I further maintain that a culturally responsive curriculum is a practical tool that complements the culturally responsive pedagogical research in the field today and is responsive to students' culture and intersectional identities. Further, this curriculum design recognizes the varied cultures of students in the classroom and is grounded in culturally responsive teaching, with the added layer of modifying teaching strategies in the STEM classroom. The rationale behind this is so that the dominant, westernized modes of teaching that often silence and implicitly oppress do not pose a hindrance to the learning of Black and Latinx students.

Further, a culturally responsive STEM curriculum creates a balanced relationship with students, whereby the teacher is the guide, facilitator, or even a learner participant within

the classroom. Still, further, it challenges racial stereotypes by introducing contributions to the STEM fields from a culturally responsive sensitivity lens and an intersection of people who may not otherwise be regarded as contributors to the progress in STEM fields. I envision a culturally responsive STEM curriculum as one that addresses issues, within the curricular content, learning artifacts, and problem-based, real-world challenges that may arise from the racism that has affected the environment, the health of certain classes of people, the medical advances or setbacks, and the implications behind these technological advances.

Adjapong maintains that “Scholars such as Ladson-Billings (1995) and most recently Paris and Alim (2017) have argued for culturally relevant and sustaining pedagogies” (p. 15). I concur and maintain that culturally sustaining pedagogies prompts STEM educators to go beyond the culturally relevant and responsive to embody the “valuing and maintenance of our multiethnic and multilingual society” (Paris, 2012, p. 2). I posit that the use of both culturally responsive and sustaining curriculum in STEM learning spaces serves as an explicit resistance to the hegemonic practices often found in Western Modern Science and in other STEM disciplines that are framed in dominant culture narrative. The curriculum I developed serves as a consideration for using, to support our multicultural and multilingual students in STEM learning spaces.

This project is rooted in a framework I designed called Culturally Responsive Aesthetic Learning Constructionist Model (Figure 1.0), which explores culturally responsive pedagogy, a constructionist learning model, and aesthetic learning theory. Culturally responsive pedagogy is derived from Gay’s distinction of culturally responsive teaching, which is defined as “using the cultural characteristics, experiences, and perspectives of ethnically diverse students as conduits for teaching them more effectively. It is based on the assumption that when academic knowledge and skills are situated within

the lived experiences and frames of reference of students, they are more personally meaningful, have higher interest appeal, and are learned more easily and thoroughly” (Gay, 2010, p. 106). Constructionism supports student-centered learning that enables students to discover and extend their learning from information and experiences they already know. Further, this framework originates from the work of Seymour Papert (1980/1993), who studied under cognitive development scholar, Piaget, and who regarded students as “epistemologists who are the active builders of their own intellectual structures” (Papert, 1980/1993, p. 19). The curriculum is developed using themes that are comprised of Aesthetic Learning Theory, which is akin to a constructionist model and enables students to have “aesthetically-engaged learning experiences” (Uhrmacher, 2009, p. 613) in the classroom. I designed a conceptual model to support the development of the curriculum.

The model shows how both the student and teacher are joined in an equal stratum that supports teachers in using differentiated teaching strategies to support students with multiple intelligences.

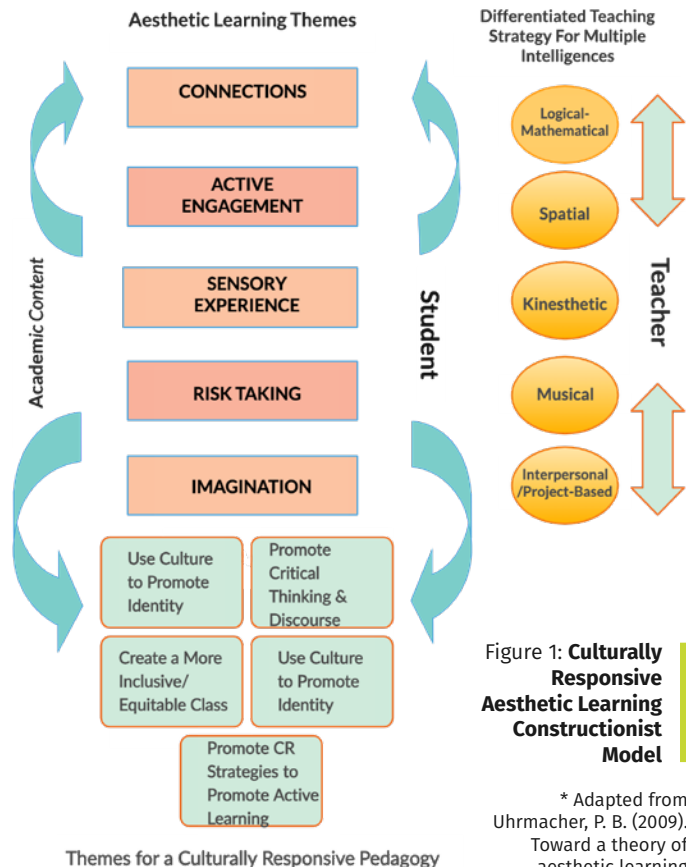


Figure 1: **Culturally Responsive Aesthetic Learning Constructionist Model**

* Adapted from Uhrmacher, P. B. (2009). Toward a theory of aesthetic learning experiences. *Curriculum Inquiry*, 39(5), 613-636.

I suggest supporting students in developing a STEM identity and foundations for academic success in STEM learning spaces. STEM identity is the process of how Black and Latinx students can form an internalized association to STEM as they realize success in STEM learning spaces, make connections between themselves and the STEM content, and are introduced to others from their culture who are successfully engaged in STEM majors and professions. In framing the curriculum in the pedagogical and learning theories presented, I aim to reduce the social barriers and lack of preparation that Black and Latinx students often face in STEM programs and to enable these students to develop a positive STEM identity for themselves that will result in their active participation in STEM learning spaces.

The model is designed so that one or more of the five culturally responsive themes that I designed emerge within the learning space, as a result of the successful utilization of the model. The purpose of the tenets is to link culturally responsive and culturally sustaining pedagogies to the STEM curriculum I designed that is highlighted in this article. The intention is to integrate the themes that emerge from the tenets into the world of curriculum design. There is no room to discuss the details of the tenets, as this is a topic for another article; however, the following summary presents the salient points of the tenets that can be used for curriculum design, in order to frame the curriculum in culturally responsive and culturally sustaining pedagogies. The STEM curriculum I created using the tenets is an example of an innovative approach to using culturally responsive and culturally sustaining pedagogical strategies toward design and implementation of curriculum.

Tenets of Culturally Responsive and Sustaining STEM Curriculum

The following tenets are a basis for developing a culturally responsive and sustaining STEM curriculum, to promote student achievement utilizing the funds of knowledge and cultural achievements of students:

1. Use Culture to Promote A STEM

Identity. For a more equitable climate to exist for the ethnically and linguistically diverse students in the classroom, the curriculum and instructional practices must be examined, and the pedagogy of the instructor must be questioned by the instructor. This questioning leads to

the emergence of critical pedagogy, which will then lead to an amended awareness, enabling her to examine her power in society, in the classroom, and the effects such power may have upon the students' sense of self and their ability to learn.

The concept of STEM identity is informed by Zirkel (2002), who posits that “representations of opportunity are correspondingly encoded in the identities they form in adolescence, and [they] pursue only that which they imagine as possible” (p. 358). Freeman and Freeman (2004) present the idea that through the inclusion of culturally relevant texts into the curriculum and classroom, students from culturally and linguistically diverse backgrounds learn to understand the content in the books more fully, as well as develop a clearer identity of who they are through the connection with those texts.

2. Promote Critical Thinking and Discourse.

Using this theme will enable students to use their culture, their living environment, and their academic environment as a backdrop to acquiring knowledge around history, social studies, the sciences, and a host of other disciplines, that will be influenced by the cultural experiences and funds of knowledge of each student. Moll and Gonzalez (1994) refer to this as students using their ‘funds of knowledge’ to refer to historically accumulated and culturally developed bodies of knowledge and skills essential for household or individual functioning and well-being” (133).

3. Create a More Inclusive and Equitable

Classroom Culture. A heterogeneous cooperative grouping of learners, combined with culturally responsive programming of instruction is required, to not only support the ELL and IEP students who may be pulled out for daily specialized instruction but also to create an inclusive community of learners who are supportive of those who miss part of the lesson conducted in a general population classroom. Gay (2013) posits that “[the] emphasis on “teaching to” cultural diversity helps students acquire more accurate knowledge about the lives, cultures, contributions, experiences, and challenges of different ethnic and racial groups in U.S. society, knowledge that is often unrecognized or denigrated in conventional schooling” (p. 49).

4. Use Cultural Responsiveness and Sustaining Practices to Promote Student Achievement.

Having a focus on culturally responsive and instruction for ethnically and linguistically diverse populations is central to the promotion of student achievement. Gay (2013) views culturally responsive teaching as a way to provide an equitable opportunity to accept differences among students of diverse cultures without attaching problems and pathologies to the culture - but instead to view the cultural differences as assets to enrich the learning spaces. Students will thereby interpret that the inclusion of their culture indicates that they are cared about, thus creating a space by which learning can be promoted.

5. **Promote Intellectual Strategies to Promote Active Learning.** Culturally responsive and sustaining pedagogy and participatory practices that include the students and their culture will help ensure that not only will the students receive affirmation that their culture is responsive within the school structure, but they will also receive affirmation that they are included and accepted in the school culture, and are an important central element to their learning achievement. Paris (2012) argues for “[supporting] young people in sustaining the cultural and linguistic competence of their communities while simultaneously offering access to dominant cultural competence” (p. 95).

It is my goal that through the use of the aforementioned theoretical frameworks and curricular approaches that students realize the evolution of their STEM skills and knowledge constructs from positive experiences in their STEM learning environments and that their STEM identity is actualized from their experiences, work, and products created from the lessons that nurture problem-solving, critical thinking, and ingenuity.

The Curriculum Design

I created a culturally responsive and sustaining, problem-based, aesthetically driven STEM curriculum. This curriculum aims to teach critical reasoning, computational thinking, problem-solving, and inclusive design thinking skills. Moreover, the curriculum design engages students using inclusive, culturally responsive methodologies that are framed within aesthetic learning themes, to enable students to construct skills that allow

them to continue a path of lifelong learning. The purpose of the curriculum design is to empower teachers to create a learning space that is inclusive for multiple modes of learners and to ensure that their lesson plans are facilitated in culturally responsive ways that support student cultures, student preferred learning styles, and the varied multiple intelligences of their students, to allow their students to develop a deeper connection to the STEM academic content. The explicit purpose is to support students in developing and broadening skills in engineering, computer science, science, and creative technologies. Further, the curriculum aims to support students in attaining confidence in the STEM fields through the development of their own STEM identity, to develop deeper interests in STEM, and improve learning outcomes. These intended outcomes are presented in lesson plans that use what Carrier (2011) terms as “effective strategies for teaching science vocabulary. The job of science education is to teach students how to use thematic patterns of science to communicate meanings, talking science to solve problems in writing or speaking about issues in which science is relevant” (p.1). Further, the curriculum aims to enable students to experience doing and being science (or computer science or engineering) through hands-on, problem-based learning that enables them to make sense of what is taking place in their lab activity, or while coding and debugging their app, or through engineering and testing a structure. It is through this method of experiential learning that students will acquire the natural way of deriving the vocabulary. Teachers who facilitate the curriculum can:

[P]romote students’ dialogue as they have instructional conversations. We need to provide students with opportunities to use their colloquial language and translate back and forth with scientific and technical terms. We can use this strategy, called interlanguage, to discuss the different explanations of the students’ experiences in the classroom. (Carrier, 2011, p. 2)

As an example of a method to support students in using thematic patterns in engineering to make meaning of concepts, is if students were engaged in developing a roller coaster, then

students would learn about potential and kinetic energy at the moment they experience the concept of those types of energy during the build or test of the roller coaster - students will learn that objects have their greatest potential energy at the peak of the highest part of the roller coaster, and, through various lab tests, will understand the concept of kinetic energy when the object barrels down the incline of the roller coaster. Such strategies are responsive to the learning needs of all students, regardless of their English proficiency level, as they are given adequate time in a learning space to expand their STEM funds of knowledge they need to persist and thrive in STEM courses and activities.

The curriculum design also presents, through its pedagogical strategies, outlined for teachers to use, a space for discussion regarding who is participating and benefiting versus who isn't and why as it relates to technological and innovative advances in society. Moreover, the curriculum design provides for the promotion and encouragement of active student participation in STEM learning spaces and empowers students to utilize both their cultural voice and evolving STEM proficiency to contribute as full participants in STEM environments who demonstrate a sense of belonging. In addition, the curriculum is designed in a way that integrates the STEM domains of science, computer science, engineering, and creative technologies, thereby resulting in the development and implementation of interdisciplinary lesson plans and teaching strategies. Lastly, the curriculum

is developed with the cultural background and prior experiences of its students placed at the forefront of its design.

On the other hand, teaching the students from a transdisciplinary position also enables students to develop a holistic knowledge construct from using two or more STEM disciplines within the same unit of study to produce a product or engage in a problem-based challenge. The curriculum provides a platform that carefully instructs the reader on ways to envision a culture more broadly than simply one revolving around race.

Curriculum Implementation

Before the curriculum implementation, I met with my teaching team to engage in a series of exercises that enabled us to reflect upon and discuss as a collective our pedagogical strategies, biases, value systems, and levels of understanding of the culture of our students and the various cultures within our team. Utilizing Carol Rodgers' (2002) four-phase reflective cycle (Figure 2), we explored the roles of our presence in classrooms, described and discussed classrooms we have taught in and analyzed our teacher/student talk ratio (as best as we could remember), the content of previous STEM lessons, and what was said, and what we have done to experiment with different methods of teaching, to slow down and attend to student learning in a more personal, human way. In addition, upon utilizing

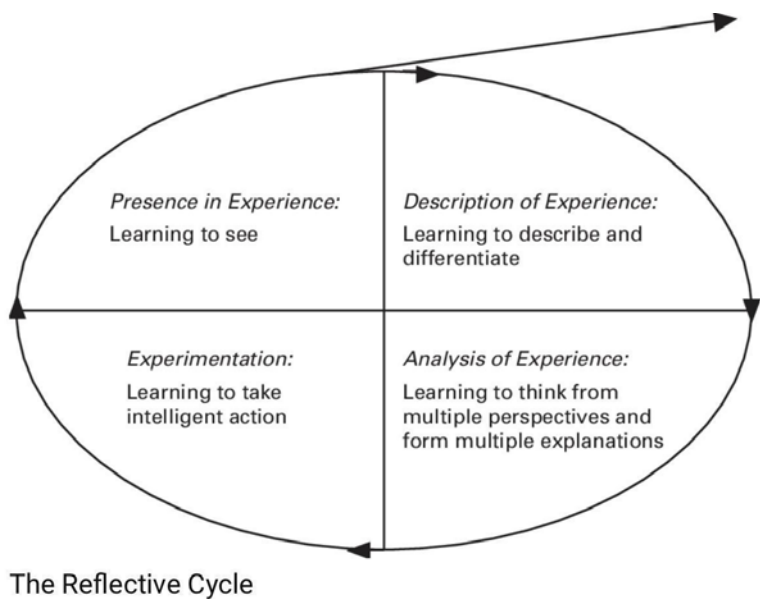


Figure 2:
Carol Rodgers' Reflective Cycle

* Adapted from Rodgers, C. (2002). Voices inside schools. *Harvard Educational Review*, 72(2), 230-254.

the reflective cycle we agreed that we would solicit structured feedback from our students so we can begin to distinguish between what we think we are teaching and the knowledge that students are acquiring. We agreed to take seven to ten minutes at the end of every lesson to solicit feedback, as well as give space for the students to share their thoughts on the lesson.

The culturally responsive and sustaining STEM curriculum was implemented through a STEM afterschool program facilitated by STEM Kids NYC, a 5-year-old nonprofit organization I founded and currently serve as the Executive Director. STEM Kids NYC provides PreK-12 STEM programs in computer science, science, engineering, and robotics and serves school, community-based, and corporate partners, whereby it offers weekly STEM afterschool programming, summer camp, and weekend events in and around the New York City, Queens, Bronx, and Brooklyn communities. The students who participated in the curriculum implementation project featured in this article were approximately 25 high school students who identified as female and who belonged to the following cultural groups: African, Asian, Latinx, and White. The students attended either specialized high schools or public schools in New York City that were considered top-performing schools. The setting was a well known community-based organization, located in midtown Manhattan, and was an afterschool site of STEM Kids NYC. The students registered on their own for the STEM program and were not provided any incentives to be a part of the program.

Observations, Student Feedback, and Themes That Emerged

The following section represents observations and themes that emerged from analyzing feedback from students. This feedback came from structured surveys and informal interviews that were organized around particular approaches that were either used throughout the curriculum implementation project or were generated as a result of the weekly sessions with the students.

Students Used Risk-Taking, Sensory Experience, and Connections to Acquire Knowledge

Testimonials that emerged from a survey given to student participants, after a robotics lesson, and whose names are listed as pseudonyms to

protect their identity, revealed that students used persistence, hands-on experiences as tinkerers, and solving problems with their peers to support their knowledge acquisition:

Brittany: I enjoyed it a lot. We did hard, yet satisfying work that was explained well.

Jessica: I loved my experience at the program. I learned a lot and it was very fun to connect something I love STEM to other stuff I love, like art. My favorite part was probably building things like robots. I never expected myself to create something that worked so well with my own two hands.

Marta: There was a lot of troubleshooting that happened, but I got to learn more about engineering, it introduced me to a lot of information that I wasn't able to learn in school.

Francine: I got to work with a lot of materials that I would otherwise probably have never been able to work with. I am happy I got the opportunity to experience this at some point in my life and what I was most excited about was the Ozobot robot and maze project. In addition to that, we were able to work with batteries and circuits as well as small LED panels.

Helene: It was very interesting to learn about the circuit and how to use Ozobots since I haven't had the opportunity to practice anything in the STEM field anywhere else.

Amy: Being in this program has allowed me to see the potential with myself; I was surrounded with such amazing and inspiring individuals which helped motivate me to do my very best. I learned how to connect my creativity with computing and circuits.

Beatrice: I liked it. I thought it was very informative and also exposed me to different tools in the STEM field that I don't think I would have otherwise found out about. For example, coming into this I had known nothing about Ozobots but this helped me understand it better and the different skills associat-

ed with using them. I also found it nice to work with the women helping run the program because it was inspiring to see women interested in and working in the STEM field.

Upon review of the narratives of the above students, it's clear that the STEM project created a positive impact on the students, and their testimonials revealed in their narratives that their STEM identities were either formed or strengthened. "An identity is a "general sense of self with reference to groups or particular content" (Renninger 2009, p. 109). In other words, an identity develops in relation to and through interactions with others, making identity inherently social in nature. In the past decade, science education scholars have been examining science identity with the framework proposed by Carlone and Johnson (2007).

The feedback from the students reveals that the teachers and I used the STEM content and differentiated their teaching strategies to enable them to utilize various aesthetic learning themes, with an emphasis on their being comfortable with taking risks. Many students shared their willingness to try something they had never done before, thereby showing evidence that the learning environment enabled them to develop their knowledge constructs by taking risks. In addition, the students were afforded the freedom to use their sensory experience in the hands-on activities, as well as their connections with the STEM academic content to tinker with the robots and increase their knowledge acquisition on robotics.

Culturally Responsive Data Supported Students in Their Developing Their Critical Thinking, Interest in STEM, and Sociopolitical Consciousness

I maintain that culturally responsive and culturally sustaining pedagogies can be used to further discussions in the field of education regarding ways to support students in developing identity, student voice, and critical consciousness. In one of our sessions, where I began an introduction to virtual reality and augmented reality programming, I facilitated a discussion that enabled our students to brainstorm issues that affected women and girls specifically. The intent of the virtual reality and augmented reality lesson was to promote critical thinking, discourse, and sociopolitical consciousness. I began our

session with the customary introduction of a STEM cultural female icon: Ashley Baccus, who is a black woman and a neuroscientist, and created a virtual reality experience that enables the user to understand the experiences of black women in a hair salon, to bring attention to racial prejudice.

After the students viewed the video, they brainstormed their ideas on what their virtual reality program would do to educate members of our society about a particular prejudice or microaggression. Ideas discussed throughout the class centered on issues involving domestic violence, date rape, body image, and social media and privacy.

After the students learned to program their own virtual reality experiences, they supported each other by sharing other ideas to further improve the designs of each others' program. The result was a series of virtual reality or augmented reality designs that provided education and awareness on issues they felt adversely affected girls and women. One student commented, "I am pleased that I can showcase my ideas in this way. I never thought of the social perspective of what we are working on."

After the virtual reality and robotics projects were complete, I engaged with the students in a forum, to allow them to create discourse with each other, examine and analyze each other's projects. In this activity, I wanted to explore how the students used their critical consciousness to apply it to analyzing phenomena that centered on giving females voice and freedom to speak out about social issues that affected women. Some of our student participants' responses were:

Sara: Something I'm excited about is continuing to learn these robots and it's really fun.

Mona: I want to give a shout out to my neighbor because we had some great ideas and it turned out to work nicely. It was very fun.

Asia: I felt inspired by the video we watched earlier about the roboticist and how she made her technology more associated with the social impacts and community. So I'm thinking of myself that the robots here are kind of small but I see it as a start. So I think it's cool.

Though many of the observations and analysis from the interviews did not reveal students' developing social consciousness, the analysis did reveal that students who acquired STEM knowledge through the development of their knowledge constructs were empowered to persist in the STEM learning space and gradually formed a STEM identity for themselves. Student respondents completed an end of lesson survey after an engineering lesson that had posed a challenge to some students, due to our introducing tools to complete the lesson that was unfamiliar to some. Further, it is clear many students persisted and renewed their confidence in themselves as students who were capable of success in STEM:

Jackie: I like the idea that I can do engineering. My favorite part at the [afterschool site] is that I can learn from myself when troubleshooting. I feel very much in control and it helps because I'm a visual learner.

Clara: I don't take science classes at school, but I do enjoy the experiments we do at the [afterschool site]. My favorite activity was drawing the maze and having my robots run across them.

Jules: I personally love/prefer to do experiments and presenting ideas because I am not a great test-taker. This is also why the [afterschool] is great. I get to partake in science without having to worry about an exam grade.

Sadiya: I liked formulating our own experiments and labs that we get to analyze ourselves. Working with others to develop systems and circuits made our daily tasks easier to do.

Bella: I got a little frustrated when it wasn't working but I think it was still exciting because I was figuring out with my partner and everybody around me. That was nice. The fact that we were all frustrated but working through was cool.

The observations and the data analysis show that, as a result of having the freedom of bridging their prior knowledge to the academic content and working within a context to be able to take risks, as well as fail without negative

consequences or judgment, our students developed positive connections with their teachers and experienced their informal STEM learning space as a positive one that enabled them to develop a voice, a STEM identity, and an experience of a sense of achievement in completing labs and activities they once found difficult.

Conclusion

Even though urban classrooms are comprised of students from diverse cultures, there is often evidence of a lack of inclusion or equity within the learning environment. This mismatch often results in a deterioration of possibilities for student engagement and learning. Urban classrooms are often comprised of students who want to learn and who wish to be supported in their knowledge acquisition.

When there exists a lack of student knowledge acquisition and support in the classroom, there is often a maelstrom of events generated that quietly erode the possibilities for student academic achievement, and this erosion is more demonstrative for underrepresented students, particularly students of color. Irvin et al. (1997) posit that "any given student's quality of motivation reflects an interaction of characteristics of the individual and the environment surrounding her or him" (p.41). Further, "too many students of color have not been achieving in school as well as they should (and can) for far too long [and] this disempowerment must stop[.] Classroom teachers and other educators need to understand that achievement or lack thereof, is an experience or an accomplishment. It is not the totality of a student's personal identity" (Gay, 2010, p.1).

Within academia, there exists an increase in research and academic reporting on the need for more culturally relevant or responsive instruction in STEM education, calls for supporting multiple epistemologies in STEM education, evidence of innovations in science-based education that advance school achievement in students of color, and even calls for diversity and culture in the evaluation of STEM efforts that seek to improve STEM outcomes for underrepresented groups.

The core element that will support the success of a widely used culturally responsive STEM curriculum will be the existence of a collaboration between students, educators, families, community partners, STEM professionals, and policymakers who are all engaged with

each other to bridge the gap between school curriculum and the immediate need for schools to prepare students for STEM skills that can lead to further academic exploration through a STEM major, acquisition of a STEM job, and/or forming a STEM identity, thereby leading to possibilities for academic achievement.

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